

No.

FROM THE METEOROLOGICAL REPORTER TO THE  
GOVERNMENT OF BENGAL,

TO THE OFFG. SECRETARY TO THE GOVERNMENT OF BENGAL,  
GENERAL DEPARTMENT.

*Dated Calcutta, the 13th January 1873.*

SIR,

I HAVE the honor to submit herewith a paper describing the prevailing winds of Northern India, and discussing their causes and their relation to temperature, rainfall, &c., as far as the data at present accessible to me have enabled me to deal with these important questions. The paper having been prepared specially with a view to publication in a scientific journal, is, in some few passages perhaps, somewhat more technical than it should be had it been intended merely for popular information; but such passages are, I believe, very few, and all the more important parts, viz. those which deal with the course of the winds, the causes and distribution of the rainfall and temperature, &c., will, I think, be found quite comprehensible to ordinary readers. In the general report on the administration of Bengal for 1871-72, which has come into my hands within the last few days, the Lieutenant-Governor has truly observed that "we still know little of the course of the monsoons, of the circumstances under which the summer rainfall is thrown sometimes on the east, sometimes on the west of the Bay of Bengal, and under which it is sometimes abundant in Bengal and scanty in the North-Western Provinces, and sometimes, as in 1872, almost deserts Bengal and falls in great quantities in Northern India." Further, "we still do not know whether the rainfall of Northern India is most connected with the rain-bearing currents, which, coming to Bengal from the south, are deflected to the west by the Himalayan range, or with those that come up from the western coast. Still less we know whether the south-easterly currents, which not unfrequently prevail in Bengal in the latter part of the rainy season, and the considerable after-fall which is not unusual in October, have any connection with the currents which cause the north-eastern monsoon of the Bay of Bengal. It is most desirable that these subjects should be studied." \* \* \* \*

2. I believe that in the paper now submitted, it will be found that several of these questions have been answered for Northern India. Those which remain to be considered are such as relate to the irregularities of the seasons; and on this subject I have already written somewhat in a paper published in the Asiatic Society's Journal, a copy of which I submit herewith. But any comprehensive and satisfactory discussion of this extremely important topic is, I fear, as yet

impracticable. It will be seen that owing to the imperfection of some of the data available, to the inaccessibility of those actually on record for a large part of India, and to the entire absence of any from the greater part of British Burmah and much of Bombay, the area I have been able to treat of is only a fraction of that which influences and is influenced by the monsoons; and the treatment of even this is less satisfactory than I could have wished. In order to investigate satisfactorily the irregularities of our seasons, it is obvious that we must know in the first place what are the normal, that is, the average conditions over the *whole* area; the varying temperature of which is, as I have shown, the chief determining cause of the monsoons. When data shall have been afforded by all India that can be compared and correlated with those of Bengal, and when they shall have been rendered equally accessible, I am not without a hope that it will be found possible, to a considerable extent, to explain the irregularities of our seasons; it may be in some degree even to forecast them, although this must seem a bold expectation in the present state of meteorological science, and would perhaps be unduly sanguine in a country less favourably situated.

3. It is owing to the very remarkable facilities for meteorological inquiry that are afforded by this country in virtue of its geographical position and features, that I have been able to trace out, and even measure approximately, the relative importance of the two agents heat and vapour, which are the ~~more~~ immediate causes of the winds, and to throw light, I believe, on several other questions which are still debated among meteorologists. Partly for this reason, and also because the descriptive meteorology of India is a subject in which much interest is felt in Europe, I would ask His Honor's permission, should the paper be printed for the use of Government officers, to restrict its circulation to official circles, in order that it may be communicated to the Royal Society of London for publication in their transactions.

4. When lately in England, I showed a part of the work to General Sir R. Strachey, and he offered to communicate it to the Royal Society when completed. By availing myself of this offer I shall reap the advantage of the criticisms of a body eminently competent to discuss the questions treated of, and I shall probably obtain many very useful and important suggestions for future guidance.

5. I should observe that the manuscript herewith forwarded having been prepared with this view, the Indian names, with a few exceptions, are spelt on Sir William Jones's system, which is now generally followed in scientific publications in Europe. If printed for official purposes, I would prefer to adopt the form of spelling ordinarily in use in India.

I have the honor to be,

SIR,

Your most obedient servant,

*Meteorological Reporter to the Govt. of Bengal.*

*The Winds of Northern India, in relation to the Temperature and Vapour-constituent of the Atmosphere. By HENRY F. BLANFORD, F.G.S., Meteorological Reporter to the Government of Bengal.*

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## INTRODUCTION.

It is my object in this paper to describe the normal wind currents of Northern India, and their annual variation; and to trace out their origin and causes in so far as these can be discovered in the local physical changes of the atmosphere. For this kind of inquiry, India offers many peculiar advantages. At opposite seasons of the year it exhibits an almost complete reversal of the wind system and of the meteorological conditions depending on it, or on which it depends: its almost complete seclusion, in a meteorological point of view, from the remainder of the Asiatic Continent, by the great mountain chain along its northern border, simplifies, to a degree almost unexampled elsewhere, the conditions to be contrasted, by limiting them to those of the region itself and of the seas around; while it presents in its different parts extreme modifications of climate and geographical feature. In its hill stations it affords the means of gauging the condition of the atmosphere at permanent observatories up to a height of more than 8,000 feet, and in the loftier peaks and ridges of the Himalaya, at temporary observing stations, up to the greatest elevations to which man can ascend, when unaided by the balloon. The periodical variations of temperature, vapour tension, pressure, &c., both annual and diurnal, are strongly marked and regular, and their changes proceed so gradually that the concurrence and interdependence of their several phases can be traced out with much precision, even in the unanalysed registers.

These numerous and great advantages indicate this country as preëminently a field for the future study of meteorology. Most of the great problems of the science are here presented in the form of *instantiæ ostensivæ*, and comprehensive systematic observation, intelligently conducted, is all that is wanting to place them at the command of European science.

What James Prinsep, Colonel Sykes, Dr. Hooker, and General Strachey, have already effected in this field by their own unaided labours, is too well known to need more than a passing reference; and it is mainly owing to the exertions of the latter, acting both independently and in concert with the Asiatic Society of Bengal, that within the last few years a beginning has been made, at the expense of the Government, to gather its fruits more extensively. In 1865 the first steps were taken by the Governments of Bengal and the North-Western Provinces to obtain regular meteorological registers from a number of selected stations, under the charge of a special Government officer for each Government. Up to that date the only regular observatories had been those of the three Presidency towns, with four other stations in Bombay, that of Trivandrum and Agastyamullay in Travancore, and that carried on for three years by Colonel Boileau at Simla. Attempts had indeed been made in previous years to register the rainfall, temperature, and, in some cases, other kinds of observations, through the agency of the medical officers of the East India Company; but, owing mainly to the absence of any organized control,

the results were for the most part of little value. Even after a beginning had been made on a better system, owing to various difficulties arising from local causes, a year or two elapsed before the system could be brought into good working order; but there has been a marked improvement year by year, and as the Governments of most of the other provinces have since taken up the scheme, regular observations are now carried on over the greater part of the empire.

The results are not indeed in all cases accessible, and in some of the more remote provinces, where the facilities for scientific work are less than at the older seats of Government, there is still much to be desired. It is impracticable, therefore, at present to extend the discussion of my subject much beyond the geographical limits I have adopted. These include Bengal Proper and its dependencies, Orissa, Behar, Assam, and a portion of the Arakan coast; the North-Western Provinces with Oude, and a part of Rajpootana; the northern part of the Central Provinces, and the Punjab.

The data from all these, except the last and Upper Assam, that have served as the materials for this discussion, consist of registers of the temperature, hygrometry, pressure, wind direction and velocity, and the rainfall; also in some cases the temperature of radiation. In the case of the Punjab, I have been able to use only the thermometric, hygrometric, wind and rainfall data, and some of these are less complete and satisfactory than I could have wished. Dr. Murray Thomson's reports for the North-Western Provinces, and Dr. Townshend's for the Central Provinces, have, however, furnished very ample and excellent materials, and these gentlemen and Mr. Elliott of Roorkee have taken much pains to ascertain with accuracy the constants to be applied to the observations of atmospheric pressure in their provinces, in order to render them comparable with those of Bengal. But for the cordial co-operation of these gentlemen, it would have been impracticable to collate materials from so large an area for comprehensive discussion.

The leading geographical features of the country are too well known to necessitate any detailed description. In describing the winds, I have adopted the following divisions, most of which correspond to natural orographical divisions,—*1st*, the Punjab, formed by the lower plain of the five rivers, and the smaller plateau above the Salt Range that lies along the foot of the Hazarah hills; *2nd*, the Gangetic plain, which extends along the foot of the Himalaya from the Indo-Gangetic water-shed to the commencement of the delta at Rajmahal; *3rd*, the plateau of Rajpootana and Bundelkund, lying to the south of the Gangetic plain and drained by its river; *4th*, Central India, which term I have for the present purpose restricted to that portion of the flanks of the Sâtpoora range which is drained by the upper waters of the Wynebunga and the Nerbudda; *5th*, Western Bengal and Orissa (this consists of two distinct parts, viz. the plateau west of the Gangetic delta and the alluvial plain of the Orissa coast); *7th*, the Gangetic delta; *8th*, the Assam valley; and *9th*, the coast of Arakan as far south as Akyab. Some further details of each tract, and the positions of the several stations, the wind registers of which have furnished the materials of the discussion, will be given in the text.

## PART I.

### DESCRIPTION OF THE WINDS.

*The Punjab.*—For illustrating the winds of this region, I have the four stations Rawul Pindee, Lahore, Mooltan, and Dera Ishmail Khan. The first is situated in the north-east corner of the plateau north of the Salt Range, and near the foot of the Hazarah hills, at an elevation of 1,700 feet. An open plain extends to the south and west, but on the north and east it abuts against the hills of Hazarah and the sub-Himalaya, the latter not very lofty. The second (Lahore) is on the lower plain of the Punjab, about 160 miles south-east of Rawul Pindee and 240 miles west north-west of Roorkee, at about 700 feet above the sea. The outer range of the sub-Himalaya lies 80 miles off to the north-east, and running from north-west to south-east. The third (Mooltan) is likewise on the lower plain, near the Jhelum river, 190 miles south-west of Lahore, and is about 400 feet above sea level; and the last (Dera Ishmail Khan) is situated on the main stream of the Indus, 120 miles north by west of Mooltan, and 200 miles west of Lahore. The Sulaiman Range, which lies to the west of the Indus, running parallel with the river, is about 50 miles distant from Dera Ishmail Khan; but, nearly opposite to the station, the valley of the Gomul debouches from the uplands of Afghanistan, and affords a passage to the winds from the west and north-west. On the north, at a distance of 24 miles, the hills of the Salt Range, rising to 4,600 feet, advance to the river, which here issues from the range and affords a passage to winds from between north and north-east; while to the east and south the great unbroken plain of the five rivers stretches away in the direction of Lahore and Mooltan.

The wind registers of these stations extend over a period of a little more than three years. For three months at Lahore and one month at Mooltan, only two years' observations are obtainable; so that the data are less complete than those for other parts of our area, and, perhaps in consequence, they exhibit greater irregularities.\* The observations are those of the daytime only, viz. at the hours of 10 A.M. and 4 P.M., which are also those of the Gangetic valley stations and of the Central Provinces.

Beginning with Rawul Pindee, we find a general predominance of west winds, the annual proportion of which is 42 per cent. of the observations. East winds are rather more than half as numerous, and amount to 24 per cent. Winds from the north-east (4 per cent.) are the least frequent, and those from the remaining quarters in

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\* I cannot but think that they are, to a considerable extent, vitiated by another cause, viz. the omission to record calms. Dr. Neil, who superintends the Punjab registers, assures me, indeed, that absolute calms are of rare occurrence in the Punjab; but I must confess I cannot think that Lahore, for instance, differs in this respect so greatly from Roorkee and Agra as the registers seem to show: and since it is clear that the registration of calms at the Punjab stations has been uniformly neglected, the position of the wind-vane being always recorded as a wind-direction, some doubt must still attach to the probable frequency of calms in this region.

Since writing the above, I have been informed by Dr. Calthrop that calms are very common in all parts of the Punjab.

no case much exceed 7 per cent. The prevailing directions are undoubtedly mainly determined by the trend of the hills to the north of the plateau, and that of the Peshawur valley beyond the Indus. East winds attain their maximum, and west winds their minimum, in July. The latter are chiefly predominant from October to May, and the former are least frequent in November. In this latter month south-west winds are almost as frequent as those from the west, while in August south-east winds attain their maximum frequency, still subordinate in importance to those from the two dominant quarters. An annual rotation of the winds is slightly, but unmistakably, indicated by the table. From April to July the veering is by north-west and north to east; and from July to December through south-east, south, and south-west to west.

The geographical position of Dera Ishmail Khan, under the lee of the Sulaiman Range (trending from north to south), and at a distance from the Himalaya, determines a very different system of wind currents. Here north-east winds predominate on the average of the year, amounting to 26 per cent., and west winds (5 per cent.) are least numerous. Winds from the east and south-east amount in each case to 15 per cent., and those from the remaining four points to between 9 and 11 per cent. In the cold weather months, *i.e.* from November to April, west, north-west, and north winds, are at their maximum, always subordinate, however, to those from north-east; while from May to October, winds from between north-east and south-east contribute from 70 to 80 per cent. of the observations. The annual change is rather one of oscillation than rotation. From February to August there appears to be a gradual veering of the mean direction from north by west, through north, north-east, and east to east-south-east, and the change from the summer to the winter monsoon is retrograde, and consists in a gradual strengthening of the northerly current till the latter attains its extreme direction from north by west in January.

At Mooltan the wind system is again different. Here south-west is the predominant quarter, to the extent of 29 per cent. on the average of the year; north-west stands next in importance, and due east and west winds amount to only 2 and 3 per cent. respectively. It is possible that the low proportion of west winds may be due to some local obstacle, influencing the currents that act on the wind-vane and diverting them either to north or south of their primitive direction. But even if we admit that a portion of the north-west and south-west winds are possibly diverted west winds, the fact remains that at this station winds from the southerly quarters are equally numerous with those from northern directions, which is not the case at any other of the Punjab stations here noticed. The predominance of westerly over easterly winds, on the other hand, is a condition which also obtains at Rawul Pindee and Lahore, though not at Dera Ishmail Khan. With respect to the annual change of mean direction, the table shows considerable irregularities, which may be due in part to the cause above suggested, and in part to the inequality of the periods from which the data for the several months have been obtained. In January the resultant appears

to be decidedly north-north-west ; in February and March less decidedly north by east and north by west, and the wind then appears to back through north-west and west to south-west by south, which is its prevailing mean direction during the summer monsoon, and is most decided in September. In the latter months of the year the direction of the change seems to be reversed, and the winds veer normally and somewhat abruptly through west, to north and north by east, which is the mean direction in December.

The wind system of Lahore resembles to a certain extent that of Rawul Pindee, except that, owing to the more exposed position of the station, the prevalent currents are less exclusively east and west. The most frequent wind is from north-west (25 per cent.), and north-east is second in importance (18 per cent.). South winds are rare, and do not exceed 2 per cent. on the average of the year, and those from the three southerly points are only 22 per cent. against 52 from the opposite directions. As at Rawul Pindee and Mooltan, westerly winds preponderate over easterly, but to a less extent, the proportions being 50 to 39. The prevalent mean direction from October to April is north-west and north-north-west ; but north-east winds on the one hand, and west winds on the other, form a not inconsiderable proportion of the whole. From March onward, east and south-east winds become more frequent, and in July and August preponderate. They are not, however, very steady, and north-east and south-west winds are nearly as common as those from south-east. In September westerly winds regain their ascendancy, and veer by west towards the north in October. The annual rotation is therefore normal as at Rawul Pindee.

It results from the above analysis that the winds of the Punjab are far from uniform in different parts of the great plain. Except in the region that lies under the lee of the Sulaiman Range, currents from the westward preponderate on the average of the year, and this we shall see is a general rule throughout Northern India. On the plateau north of the Salt Range, west winds and their opposites prevail almost to the exclusion of those from other quarters ; the former coinciding with the cold and the hot dry seasons, the latter with the summer monsoon. To the south of this, northerly winds preponderate over southerly in the greater part of the Punjab, but at Mooltan the latter are somewhat in excess. In the winter months (December to February) the mean direction is west at Rawul Pindee, nearly north at Dera Ishmail Khan and Mooltan, and between north and north-west at Lahore ; diverging, therefore, from the angle formed by the mountain ranges that bound the plain on the north and west. With the rise of temperature in Northern and Central India in the months of March, April, and May, the wind currents draw round to the north-east along the foot of the Sulaiman Range ; to west over the more exposed parts of the plain : but in the latter month, or in June, when the rains are setting in over the greater part of India, reducing its temperature, and thus transferring to the Punjab the locus of greatest heat,\* easterly winds begin to

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\* See *postea*, Part II, page 31.

increase in frequency, and in July and August preponderate in the central and northern parts of this region. At Mooltan, however, as in Sindh, easterly winds never gain the upper hand, and during the height of the summer monsoon the prevailing winds come from the direction of the Arabian Coast. The south-west wind is not, however, here a rain-bearing current. It probably comes as much from the desert as the sea, and passing in its course over the heated arid plains that surround the lower course of the Indus, the increase of its temperature counteracts any tendency to precipitation which may be induced by the upward diffusion of its vapour; so that Mooltan receives on an average only five inches of rain during the five months from June to October.

Thus it appears that during the south-west monsoon the winds perform a kind of cyclonic circulation in the Punjab, converging from the plains to the south and east, and this region is the goal of the Indian portion of the monsoon. In Affghanistan, further to the westward, easterly winds are irregular and uncertain, even when the summer monsoon is at its height, and dry west winds predominate throughout this season.

*The Gangetic Plain, North-Western Provinces, and Behar.*—Of the four stations that I have selected for illustrating the winds of this region, the most northerly (Roorkee) is situated 15 miles from the foot of the Sivaliks or sub-Himalayan range, on the *Doab* or fork between the Ganges and Jumna; its elevation is 880 feet above mean sea level. The second (Agra) lies due south from Roorkee, at a distance of 190 miles, on the south bank of the Jumna, just at the point where a low spur of the great Malwa plateau abuts on the river; the station is 550 feet above sea level. The third (Benares), 320 miles east-south-east from Agra and 150 miles from the foot of the Himalaya, is also situated near the southern edge of the plain, the bounding escarpment of the Bundelkund plateau (or eastern extension of that of Malwa) being only about 20 miles to the south of the station. Benares is situated on the north bank of the river, and 255 feet above the sea. Lastly, Patna (or more correctly the civil station of Bankipore), below the confluence of the Sone and Ganges, 180 miles east and a little north of Benares, stands in the midst of the great alluvial plain of Behar, at an elevation of 172 feet.

The wind registers of the three first-named stations extend over a period of from six to seven years, and comprise day observations only, as in the case of the Punjab stations. That of Patna includes four years and eight months' observations, of which 11 months give day observations only, and the remainder the 10 P.M. and 4 A.M. observations in addition. The Patna observations are unfortunately vitiated to a considerable extent by the observer's omission to record calms, except during the last 12 months of the period. I have therefore, in computing the percentage table, taken the proportion of calms in these twelve months as an average, and reduced the number of recorded winds in previous years in relative proportion. The result, if not quite satisfactory, is at least less erroneous than it would otherwise have been.

The continuous chain of the Himalaya, skirting the northern edge of the Gangetic plain, determines in a great measure the direction of its prevailing winds. At Roorkee, where this influence is most directly felt, and where the neighbouring hill chains run almost due north-west and south-east, the winds from these two quarters greatly exceed those from all other directions, and are of nearly equal frequency, amounting together to 38 per cent. of the observations; of the remainder, not less than 41·5 per cent. are calms. At Agra the influence of the Himalayan range is less marked, and the prevailing winds are modified by other causes. Next to calms (25 per cent.), west winds are most numerous (23·3 per cent.), and north-west and east winds stand next in frequency, being respectively 10·3 and 10·5 per cent. North and north-east winds are about equally frequent (between 7 and 8 per cent.), and those from the southerly semicircle are least frequent, amounting altogether to only 15 per cent. of the observations. At this station that predominance of westerly winds which has already been remarked at the Punjab stations, is very distinct.

At Benares the proportion of calms becomes reduced to 7 per cent., and the mean movement of the air is nearly half as great again as at Roorkee. The winds from the several quarters have nearly the same relative frequency as at Agra. Thus west winds maintain their preponderance (30·5 per cent.), and east and north-west winds stand next in order. South and south-east winds are of rare occurrence, but there is a slight relative increase of south-west winds, which here form 9·3 per cent. of the observations.

At Patna the proportion of calms to winds, as given in the table, greatly exceeds that at any other station, but the great excess is in part due to the inclusion of night observations. At both Patna and Roorkee calms are twice as frequent at night as in the daytime, and at Benares (judging at least from one year's register) between nine and ten times as frequent.\* Nevertheless, after making due allowance for this difference in the comprehensiveness of the tables, Patna still *appears* to equal Roorkee and surpass all other stations in the stillness of its atmosphere; but the anemometric records of the mean diurnal movement of the air do not confirm this conclusion, and they are probably a safer guide than the column of recorded calms. The former shows the average movement of the wind to be considerably greater than at Benares, and still more in excess of Roorkee.

Winds from the north-west quarter are most frequent, being half as numerous again as those from west. East and north-east winds count second and third in relative frequency, and those from the eastern semicircle are equal to, or rather in excess of, those from westerly quarters. Winds from the south are very rare, and are almost restricted to the month of August, but those from south-east are relatively

\* Night observations of the winds were not recorded in the North-Western Provinces until lately. The proportions of calms in the day and night hours are as follows:—

Patna	...	...	276 day,	559 night	...	1 year.
Benares	...	...	37 "	358 "	...	1 "
Roorkee	...	...	156 "	408 "	...	8 months.

more numerous, and those from south-west less numerous than at Benares. Northerly winds are twice as common as southerly.

At all the stations of the Gangetic plain the winter season is that in which calms are most prevalent, and the average movement of the winds is at a minimum; November being the month of greatest stillness at the higher stations. At Roorkee, in this season, the average direction of the wind is north-west; at Agra west-north-west, or a little more northerly; at Benares west by north; and at Patna west-north-west. There is throughout this season a secondary maximum of winds from the opposite quarters,—from south-east at Roorkee, and east at Agra and Benares; and these winds, though quite subordinate to the principal currents from the westward, are of much importance to agriculture, since on them depends the occurrence of the winter rains and the fortune of the *rubbee* or winter crops. With the approach of the hot weather, the winds blow with greater force and steadiness from the westward; calms become less frequent, and attain their annual minimum in April at Agra, in April and May at Patna, and in May and June at Benares and Roorkee. The wind blows from about the same direction as in the cold season, but the westerly winds are now hot and exceedingly dry, and blow with great force during the heat of the day and the fall of the barometric tide. As the hot season advances, easterly winds gradually increase: at Patna and Roorkee this increase is very distinct as early as April, chiefly from north-east at the former and south-east at the latter station; at Benares it occurs a month later from east; and at Agra it proceeds gradually from April onwards, accompanied, however, by an incursion of south-west winds in April. This last phenomenon will be again met with, more distinctly developed, at Ajmere. At Patna easterly winds preponderate as early as May; but at Benares and the higher stations, westerly winds maintain their preëminence till the latter part of June or the beginning of July.

In the North-Western Provinces easterly winds attain their maximum in July, the first month in which as a rule the rains become general. North-east winds are at their annual maximum in May at Patna, between May and June at Benares, and at Agra in June and July. Thus, as the tables show, along the southern edge of the Gangetic plain north-east winds are more than twice as frequent in the so-called south-west monsoon as at the opposite season, when the north-east monsoon prevails at sea.

At Roorkee, from July onwards south-east winds gradually give place to those from north-west, up to the end of the rains in the beginning of October; but at Agra, Benares, and Patna, the month of August is marked by a temporary check of the easterly winds and an incursion of winds from another quarter. This is between south-east and south-west at Agra, west at Benares, and south and south-west at Patna. The latter decline in September, easterly winds resuming their sway. This feature is not peculiar to these stations, but is equally well marked in Orissa, and is perceptible even in Lower Bengal. It appears to be due to an incursion of the monsoon current from the Arabian Sea.

At stations on the southern border of the plain, the winds veer normally from west or north-west round through north and east to their extreme south-easterly direction in the summer monsoon; the opposite change is more abrupt. At Roorkee any rotation that can be detected is retrograde.

*Plateau of Rajpootana and Bundelkund.*—Dr. Murray Thomson's reports for the years 1863-69 give meteorological registers\* of the stations Beawur, Ajmere, and Jhansi. The two former stations are situated within a few miles of each other, and under similar geographical conditions; and since their registers refer to different years, I treat the whole as those of one station. Ajmere and Beawur are situated at an elevation of between 1,500 and 1,800 feet, near the western edge of the plateau, where it declines to the desert plains of Bikaner. A few miles west and north-west from the stations are some low hills, spurs of the Aravulli Range, and an outlying spur of the same range to the southward forms the water-shed between the Gangetic basin and the streams draining towards the Gulf of Cambay.

On the average of the year, winds from the west and south-west greatly exceed those from any other quarters, and together amount to 52 per cent. of the observations; of the remainder, 10 per cent. are calms. Winds from other quarters are about equally frequent, with the exception of north-east winds (8 per cent.), which are slightly in excess of others (5 to 6 per cent.). Calms are most prevalent in the winter months (October to February), during which they contribute from 15 to 20 per cent. of the observations; and they are least so in May, when they amount to only 2 per cent. North, north-east and east winds are at their maximum in the winter season, and December and January are the only months in which easterly components preponderate over westerly, or, with the addition of November, northerly over southerly: the distinction between Ajmere and Agra in this and other respects is very striking. In February west and south-west winds begin to set in with increased frequency, and in April blow with considerable steadiness; the latter attaining their annual maximum in May, the former in September, while the mean direction throughout the summer monsoon is west-south-west. Up to October this wind current scarcely veers or slackens, but in November the wind comes more from north, and eventually north by east. It is to be noticed that at Ajmere the two monsoons prevail alternately, in what may be termed their normal directions; the south-west, however, greatly preponderating in duration and steadiness, while the north-east monsoon is weak and unsteady, and much interrupted by calms. In many respects the wind system resembles that of Mooltan.

Jhansi is situated on the plateau of Bundelkund, 250 miles east by south of Ajmere, at an elevation of nearly 900 feet above the sea. From Agra it lies south by east, at a distance of 130 miles, while Benares lies 320 miles to the eastward. There are a few scattered hills about the station, "one very close to the city and

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\* Consisting of day observations only. The winds are recorded at 10 A.M. and 4 P.M.

overhanging it, another a little way off to the south-east.”\* The registers of this station, given in Dr. Thomson’s reports, cover a period of six years, but some are imperfect, specially in the earlier months of the year.

The winds at Jhansi are chiefly west or north-west and east (30, 14, and 16 per cent. respectively, on the average of the year). Calms appear to be comparatively rare, amounting to only 3 per cent., and winds from south-east are only 5 per cent. of the observations. Westerly elements predominate greatly over easterly, and northerly to some extent over southerly. In this latter respect Jhansi affords a marked contrast with Ajmere. It is probably owing to its situation on or near the boundary between the very diverse wind systems of the Gangetic plain and Central India, that at all times of the year the winds are more or less conflicting, and that the figures that express the percentage of the resultants in the table are consequently lower than at any other station except Roorkee.

In the cold weather months north and north-east winds are at their maximum, but even then they are quite subordinate to those from west, north-west, and east; and in December and in January the resultant direction is from 1 to 2 points west of north. In February and March northerly elements decrease rapidly, and in the latter month south winds attain their maximum. In April and May hot westerly winds set in, and the resultants veer back to west and west-north-west. South-west winds are frequent in April, and, after a temporary suppression in May, they recur, and are at their maximum during the three months June to August. In this latter month there appears to be a sudden incursion of east winds—a somewhat remarkable irregularity; for at Agra, Benares, and stations further eastward, at which the rainy season is characterised by easterly winds, the reverse phenomenon takes place. In September north winds undergo a sudden increase and reach their annual maximum; and in this and the two following months the mean direction is pretty steadily north-west by west.

*Central India.*—Dr. Townshend’s reports, published in the *Central Provinces Gazette*, and in the Sanitary Commissioner’s reports for those provinces, give the anemometric results of Jubbulpore and Nagpore for the three years (1869-71), together with those of other stations for shorter periods. I select these two as the most complete and trustworthy.

Jubbulpore is situated on the north, Nagpore to the south, of the belt of hills which stretches across Central India, and is now generally known as the Satpoora Range. At its northern foot this range or series of ranges dips to the alluvial valley of the Nerbudda, lying between two escarpments, and allowing an uninterrupted passage to the prevalent westerly winds. Jubbulpore is situated at the upper end of this valley, 1,350 feet above the sea, not far from the low water-shed that separates the drainage of the Nerbudda and the Ganges. North of the station the escarpment that borders the valley on the north retreats, and a gently ascending

\* Dr. Thomson’s Report for 1863. The direction of the first-mentioned hill is not stated.

plain (over which is carried the railway to Allahabad) forms a break in the table-land, and affords a channel to northerly winds.

Nagpore lies 150 miles south-south-west of Jubbulpore, on the plain that extends along the southern foot of the Satpooras, in a kind of bay between two prominent offshoots of the hill country, which is drained by the Wynegunga and its tributaries. The station is about 1,000 feet above the sea.

At both stations westerly winds preponderate on the whole, the dominant direction being west at Jubbulpore, north-west at Nagpore. East and south-east are the directions of least frequency at the former, and south-east and south at the latter station. Thus the wind veers on an average four points between Jubbulpore and Nagpore. Calms are not very frequent at either station. At Jubbulpore the mean velocity of the wind up to May is rather below that at Patna, but during the rains it is much greater. At Nagpore it is greater than at Jubbulpore in all months of the year. The velocity is highest in June, lowest in November or December.

At Jubbulpore, north and north-east winds blow pretty steadily in November and December, but south and south-east winds are not infrequent, being about half as numerous as the former. These are probably in great part local mountain winds. In January westerly elements begin to preponderate over easterly, and southerly to gain on northerly winds. South winds attain their maximum frequency in March, in which month winds from between south and west amount to 54 per cent. of the observations, while those from the opposite quadrant have diminished to 28 per cent. In April and May west and north-west winds gain the ascendant, but on the setting in of the rains the wind backs towards south-west and blows very steadily during the three months June to August from a mean direction about a half a point south of west. In September the monsoon slackens; north and north-west winds begin to preponderate, veering towards north and north-east; and in November the north-east monsoon is re-established.

On comparing this series of changes with that shown by the Jhansi registers, it appears that in the cold season the prevailing winds of Jubbulpore are from 1 to 8 points more easterly than those of the latter station; that at both stations southerly winds increase from January to March, and attain their maximum in this latter month; that west and north-west winds become ascendant in April and May, and then back towards south-west up to the setting in of the rains. At Jhansi, however, easterly winds are more frequent at all times of the year than at Jubbulpore, and specially so in August.

These two stations exhibit a sort of graduated passage from the wind system of the Ganges valley to that of the peninsular south of the Satpoora Range. This last is illustrated in Nagpore.

At this latter station the average direction of the wind in the winter months is steadily east-north-east, while winds from north-west and west are extremely rare. In February, and still more in March, the currents become unsteady and conflicting,

though the movement of the air is on the whole increasing. South winds are at their maximum from February to April, and south-west winds are not infrequent. In April north-west winds gain the ascendant, and blow with increasing steadiness in the following months, backing, however, to west, which is their mean direction in July. North winds are at their maximum in May, north-west winds in June, and west and south-west winds in July. After July northerly and easterly winds begin to increase, the mean direction veers to north-west in September, to north-east by east in October, and finally attains its extreme easting in December.

Thus, then, in the cold weather months and those of the rains, that is to say when the north-east and south west monsoons are at their height on the seas around India, the wind current/south of the Satpooras have a direction almost diametrically opposite to those of the Gangetic plain. The former blow to and from the Arabian Sea, the latter to and from the Bay of Bengal; only in the hot season do the two wind systems approximately coincide, and then they are in both regions from between west and north west, blowing from the comparatively dry region lying to the north-west towards the thermal focus of Central India and Western Bengal. The evidence of this will be given in another place.

*Western Bengal and Orissa.*—For illustrating the winds of this region, I have the three stations Hazareebagh, Cuttack, and False Point. The first is situated 2,000 feet above the sea, on one of the culminating points of the plateau that lies between the Sone, the Ganges, and the Gangetic delta. This plateau forms the eastern termination of the elevated range that, beginning with the Rajpipla hills at the Gulf of Cambay, is continued by the Gawilgurh, Mahadeva hills, and other divisions of the Satpooras to the umbilical plateau of Umarkuntuk; and, after a short break, by the not less elevated table-lands of Jameera Pat, Main Pat, Chota Nagpore, and Hazareebagh, up to the angle of the Ganges at Rajmahal. To the east of Jubbulpore it separates the Gangetic drainage from that of the peninsular, and its influence on the wind currents is scarcely less important.

Cuttack and False Point are both situated to the south of this range on the alluvial plain of Orissa. The former, 80 feet above the sea, lies close to the low hills from which the Mahanuddy debouches on its delta. The latter is one of the more prominent points of the same delta, 50 miles east from Cuttack, and jutting beyond the general outline of the coast, is fully exposed to the winds that at different seasons of the year sweep up and down the Bay of Bengal.

At all these stations winds observations have been recorded night and day, at intervals of six hours.

The tables are drawn up from the registers of three years, but it is to be regretted that in the case of Hazareebagh and Cuttack, more specially the latter, they are vitiated by the omission of calms. I infer from the more recent registers that at Cuttack in the cold weather months the atmosphere is as calm as in Behar.

At Hazareebagh, as in the Ganges valley, the prevailing winds are from north-west and west. These amount together to 46 per cent. on the average of the year. North-east is the quarter of least frequency (4 per cent.), and winds from north and east do not exceed 7 and 8 per cent. respectively. During the cold weather months the wind blows pretty steadily from between west and north-west. As the temperature increases on the approach of the hot weather, this current tends to back towards south-west and south, and in June south and south-east winds preponderate, bringing the rains from the Bay of Bengal. In July there is a further backing towards south-east and east, but in August a sudden increase of west and south-west winds implies an incursion of the monsoon current from the Arabian Sea. In September, however, the easterly backing is resumed, and east and south-east winds attain their annual maximum, amounting together to 45 per cent. of the observations. In October winds from the opposite quarters regain the ascendant, and the winter monsoon sets in from north-west by west.

It is to be observed that the annual partial rotation of the winds is here chiefly retrograde, viz. from north-west through south-west and south to south-east, and that when a semi-revolution has been completed, and the rainy monsoon has attained its extreme easting in September, it is followed and supplanted by land winds setting in from the opposite quarter of the compass. We shall presently see that the winds of the Gangetic delta follow a similar course. The incursion of the south-west current in August has been already noticed in the case of Agra, Benares, and Patna. It is much more decided at Hazareebagh, and equally so, but more prolonged and regular, at Cuttack and False Point. The mean velocity of the wind at Hazareebagh is more than twice as great as at Benares, and nearly twice as great as at Patna. At the time of its maximum in May and June, it is twice as great as when at its minimum in November and December. In point of steadiness, however, the periods of maximum and minimum are reversed. The north-west winds of November and December, if gentle, blow very steadily, and the resultants show an excess of 62 per cent. In May, on the other hand, there is an excess of 17 per cent. only in the direction of the resultant.

At Cuttack and False Point we meet with a wind system very different in its more striking features from any yet described. The land winds from north and north-west are here quite of subordinate importance, and a great predominance of those from south-west and south blowing along the shore, or obliquely from the Bay towards the hilly country of the interior, characterises Orissa and the Northern Circars. At both the above stations, winds from between north and north-east set in as early as October, and with the increasing cold of the interior and strengthening of the land winds, they become more northerly in the two following months. At False Point indeed they maintain a marked ascendancy till the end of January, veering back however towards north-east and east; but at Cuttack the veering proceeds farther, and sea winds from east and south-east predominate in this month. In February south-west winds gain the ascendant at False Point, and

south winds at Cuttack, a difference of about four points between the two stations being maintained throughout the hot weather and rainy months. With the increase of temperature in the interior, south winds at Cuttack and south-west winds at False Point increase in steadiness, backing through one or two points up to May. In June, with the setting in of the rains in Bengal, the veering again becomes normal, *i.e.* the westing increases, and this tendency is maintained till the month of August. In September the south-west monsoon slackens, and the wind once more backs rapidly through south-east and east to north-east in the month of October.

At False Point, as at most coast stations, calms are of rare occurrence. In October, the month of their greatest frequency, they amount to only 11 per cent. of the observations, while in May none are recorded. They are somewhat more frequent in the cold weather than the rains, and least so in the hot weather months. This appears to be an universal rule in Northern India. At Cuttack, to judge from one year's register, they are common in the cold weather, and in accordance therewith the mean velocity of the wind is low. The summarised register for a part of the two years 1871-72 will serve to correct the deficiencies of those of the longer period.

*Gangetic Delta.*—The delta of the Ganges may be regarded as the northern end of the great wedge-shaped depression occupied by the Bay of Bengal. This arm of the ocean affords an unobstructed channel to the interchanging air currents between the equatorial seas and the plains of Upper India. The delta lies, so to speak, in the neck of the funnel formed by the converging coasts of the two peninsulas: that on the east being bordered by a continuous mountain range, the Arakan Yoma, not less than 4,000 or 5,000 feet in height; that on the west bordered also by hills, more broken indeed, and of much less mean elevation, but still opposing a certain barrier to the free passage of the winds to and from the interior of the peninsula. At the upper end of the Bay these hill tracts advance to within 200 miles of each other, enclosing between them the united deltas of the Ganges and Brahmapootra, and farther inland the advanced plateau of the Garo Hills constricts the plain to a width of 150 miles, allowing free access to the plains of the upper provinces, but almost entirely obstructing the entrance of the narrow valley of Assam.

Of the four stations that I select for illustrating the wind system of the delta, three, *viz.* Saugor Point, Calcutta, and Berhampore, are situated along a line from south to north parallel to its western border, and at no great distance from it. The fourth (Dacca) lies 120 miles to the eastward of the last-named station, about equidistant from the sea and the eastern hill boundary of Tipperah. Berhampore, 160 miles from the coast, is 64 feet above sea level, the other stations at various less altitudes. Saugor Point, at the entrance of the Hooghly estuary, is a mere marsh, protected by embankments from submergence at high-water.

As a consequence of the physical configuration of the country, nearly the whole of the lower stratum of air that sweeps over the delta is *in transitu* between the sea

and the Gangetic plains to the westward. The Assam valley, owing to its narrowness and the abruptness of its junction with the broader Ganges valley, affords but an obstructed and tortuous passage to this stratum, and it is chiefly an upper current that, passing over the low hills of Tipperah and the Khasi and Jynteah Hills to the north of these, makes its way to or from Upper Assam as the monsoon wind.

The wind table for Calcutta has been drawn up from the hourly observations of ten years, and, notwithstanding the roughness of the observations, represents the wind system probably with as much accuracy as is attainable in the absence of self-registering instruments. The velocities are obtained from four years' observations. For other stations, three years' registers of observations recorded at six-hour intervals have been used. In two cases, viz. Berhampore and Saugor Island, the registration of calms has been neglected during the greater part of the period; the Saugor Island table is probably scarcely affected by this omission, but such is not the case at Berhampore, and I give therefore the register of one year in addition, in which calms have been recorded.

At Saugor Island south and south-west winds predominate greatly over those from all other quarters, amounting together to 52 per cent. on the average of the year. North-west and west winds and their opposites are least common, amounting to from 5 to 8 per cent. respectively. At Calcutta south winds form 31 per cent. of the annual average, and there is a slight, but decided, preponderance of westerly over easterly components. At Berhampore the case is very different. The excess of south winds over those from any other quarter is but small, and there is a difference of only 5 per cent. between them and south-west winds, which are here the least frequent. At Dacca, again, south winds preponderate, and south-east winds stand next in order, while easterly components slightly exceed the westerly.

At all these stations the annual rotation of the wind is incompletely retrograde, and such as has already been described at Hazareebagh. The winter monsoon or land wind sets in in October and becomes well established in November, with a mean direction which is nearly north at Dacca and Saugor Island, north-north-west at Calcutta, and north-west by north at Berhampore. At Saugor Island it blows pretty steadily during the three months November to January from a direction a few degrees east of north, and at Berhampore it is almost equally steady; but at Calcutta and Dacca it backs gradually towards the west, and by February blows from west by south. At Saugor Island the sea wind sets in in February, somewhat suddenly from south-west by south, and during the hot weather months backs gradually through four points of the compass, increasing in steadiness and mean velocity till the setting in of the rains in June. At Calcutta, Berhampore, and Dacca, a similar change in direction occurs, but through a greater range. Thus at Calcutta the wind backs through 8 points, at Dacca through 9, and at Berhampore through 10 points, between February and May.

On the setting in of the rains the wind veers normally (to the westward) about half a point or a point—a change small in amount, but equally distinct in all parts of the delta, in the 10-year table of Calcutta, and the 3-year tables of the other stations. In the following months, however, the winds again acquire more easting, until in September, the last month of the rains, the mean directions are S.4E. at Saugor Point, S.30E. at Calcutta, and S.70E. at Berhampore. At Dacca and Saugor Island, that incursion of westerly winds in August which is so marked at Hazareebagh and other stations already noticed, is distinct, though less striking, and it is traceable even in the Calcutta table. At the two first-named stations there is a temporary increase of south, south-west and west winds in August, and a corresponding decrease of south-east winds, such as to cause a normal veering of the resultant through nearly two points at Dacca and one at Saugor Island. At Calcutta and Berhampore this does not take place, but the backing of the wind is somewhat less between July and August than either in the preceding or following months. In October the winds are chiefly from the east, but unsteady and stormy, alternating with calms in the earlier part of the month, and northerly or north-westerly in the latter part.

In all parts of the delta the velocity of the wind is lowest in November and highest in May and June. This difference is greatest at the inland stations Dacca and Berhampore. At the former the mean movement of the air in June is six times as great as in November, and at the latter more than four times as great. At all times of the year it decreases rapidly from the coast inland. Thus at Saugor Island, Calcutta, and Berhampore, the mean diurnal movement of the wind in May and November is as follows:—

			May.	November.
Saugor Island	...	...	345 miles	111 miles.
Calcutta	...	...	209 „	82 „
Berhampore	...	...	100 „	29 „

*Assam.*—The Assam valley extends in an east by north direction along the foot of the Eastern Himalaya, from the extremity of the Garo Hills in east longitude  $90^{\circ}$  to the point where the Brahmapootra issues from the Brahmakoond gorge in about longitude  $96^{\circ}$ . Its length is thus about 420 miles, while its width nowhere much exceeds 60 miles. On the south it is enclosed by a table-land formed by the Garo, Khasi, Jynteah and Naga Hills, of which the second are the most elevated, the highest ridges being between 5,000 and 6,000 feet. The Jynteah Hills next to the eastward are 1,500 or 2,000 feet lower, and the Naga Hills still less elevated, with the exception of the Burrail Range, on the south-east and south, which rises to about 5,000 feet. Between the western extremity of this range and the Khasi Hills, is left a comparatively free passage, at a lower level, for the monsoon winds blowing to or from the upper part of Assam. On the north the Bhotan Himalaya runs parallel with the valley up to the gorge by which the great Dihong River breaks through the mountains, and affords an

open passage to the monsoons to penetrate to the region north of the Himalaya. Sebsaugor lies to the south and a little to the west of this break in the mountain chain, full in the course of the alternating currents, but sheltered somewhat by its depressed position on the alluvial plain between the two hill ranges. Goalpara, on the other hand, is situated at the lower end of the valley, due north of the Garo Hills, and completely shielded on the north by the Bhotan Himalaya.

The tables for both these stations are drawn up from the observations of three years (recorded four times daily). The Sebsaugor observations are evidently somewhat rough, but there seems no reason to doubt their general trustworthiness except in so far as they may be vitiated by the usual omission of calms. Both tables show a preponderance of easterly winds, as decided as is that of westerly winds in the peninsula of India. At Goalpara this excess of easterly winds holds good in every month of the year, and the only change in the mean direction of the wind is an oscillation through about 7 points of the compass, from east by north in March to south-south-east in July, and back again during the remainder of the year. North-east winds are most frequent in the winter months, and attain their maximum in March. West winds are also at their maximum in the same months, in which respect Goalpara resembles Berhampore. In May, east winds attain their annual maximum, amounting to 59 per cent. of the observations; but in the following months, during the prevalence of the south-west monsoon, winds from south, south-west, and west, are frequent. In respect of mean velocity, there are two epochs of maximum and two of minimum annually. The former occur in April and September, the latter in July and December. Of these the April maximum is the absolute maximum of the year, and the December minimum is generally below that of July.

At Sebsaugor winds from the north and north-east amount together to 54 per cent. on the average of the year, while those from south and south-west do not exceed 29 per cent. The air current from the direction of the great Dihong valley (possibly derived from Tibet,) preponderates considerably over that from the sea. Nevertheless the climate of Sebsaugor, though cool, is not so dry as this fact might lead us to anticipate; the rainfall is not much less than at Goalpara, and occurs at all seasons of the year: this fact leads me to doubt whether in reality any considerable body of air is drawn from the trans-Himalayan region. The winter monsoon from north and north-east sets in in October and blows with great steadiness through November and December. In January westerly winds begin to be felt, and gradually increase during the following months, chiefly from south-west, until in June they predominate over those from between north and east. Through July and August the south-west wind, the undiverted monsoon, maintains a very decided mastery, but slackens in September and ceases in October, when the winter monsoon regains its supremacy.

*Arakan Coast.*—Although geographically a part of the Burmese peninsula, this coast may fitly be treated as belonging to the Indian area in respect of the winds,

since those of the lower stratum of its atmosphere are more influenced by the heat and cold of Bengal, than by any alternations of temperature, &c., in the interior of the eastern peninsula. This is owing to the mountain chain of the Arakan Yoma, which runs from the eastern end of Cachar, parallel with the coast, at an average distance of 40 or 50 miles, down to Cape Negrais; and is of an average height of 4,000 or 5,000 feet. It would seem from the wind tables here given, that the greater part of the air currents at Chittagong and Akyab are *in transitu* to or from the Gangetic delta; but it is probable that a certain portion of them make their way up or down the river valleys that drain the western slopes and spurs of the Yoma, and, crossing the low ranges of the Chittagong and Cachar Hill Tracts, form part of the Assam branch of the monsoons.

Chittagong is situated at the south-eastern extremity of the Gangetic delta, about the junction of the great Megna estuary with the sea. To the east and north-east extends the tract of low hills above referred to, and on the very margin of which the station is built, a strip of alluvium about three miles broad intervening between the hills and the sea. Chittagong is 140 miles south-east from Dacca, and 240 east by north from Saugor Point.

Akyab is 150 miles further down the coast, at the point where the Koladyne river enters the sea. The station is built on a low point of land between the estuary and the Bay of Bengal, and the harbour formed by the estuary is further enclosed by a group of rocky islands to the southward.

At Chittagong there is no very decided preponderance of any one wind direction on the average of the year, but north-west winds are less common than others, and on the whole southerly winds are in excess of northerly, in the proportion of 42·5 to 30 per cent. As in the Gangetic delta, the annual rotation is retrograde from November to the following September; in this case through more than two-thirds of the compass: and the change from the characteristic direction of the summer to that of the winter monsoon takes place somewhat abruptly in the month of October. In the cold weather months the average direction is from between north and north-west, but less westerly by about a point than at Dacca; northerly elements preponderate till the end of February, that is to say a month later than either at Dacca or Saugor Island. Between February and June the wind works round gradually to the southward, and in the latter month it backs further to about south-east by south, which is its average direction as long as the south-west monsoon prevails over the Bay. At all times of the year the mean direction is modified by land and sea breezes. The average velocity is more uniform than at inland stations. When greatest, viz. in June, it is less than twice as great as its minimum in October or November. At the former period it is less than at Dacca, at the latter nearly three times as great. At these two stations the periods of maximum and minimum are approximately the same, and about a month later than at most stations to the westward. Calms are not very common at any time of year, and occur chiefly at the close of the south-west monsoon.

The wind system of Akyab differs from that of Chittagong in much the same way as this latter differs from that of Dacca, *i.e.* the corresponding phases of the wind's rotation occur about six weeks or two months later at the more southerly station; and while the average direction of the summer monsoon is less easterly, that of the winter monsoon is less westerly. Thus at Akyab northerly elements preponderate over southerly in April, and southerly over northerly in October, the reverse of the case at Chittagong; in other words, both monsoons continue to be felt on the coast of Akyab one or two months after the change has occurred at Chittagong. This accords completely with the results of Captain Maury's discussion of ship observations in the Bay of Bengal,\* and is also what might be anticipated from the character of the barometric changes presently to be discussed.† The result is of high importance to the theory of the formation of cyclonic storms, respecting which I shall say a few words in the sequel. One other point of interest to be noticed in the Akyab wind table is the interruption of the otherwise regular retrograde movement of the winds by a sudden westing in August through one point of the compass, followed by a return to eastward in September. This reminds us of the similar phenomenon already noticed in the wind tables of the North-Western Provinces and Bengal.

*Summary.*—From the foregoing discussion of wind registers, it appears that the wind system of Northern India is very different from that of the adjacent seas. Instead of two monsoons from north-east and south-west prevailing alternately during about equal periods of the year, we find a great diversity of prevalent wind currents, depending on the directions of the mountain ranges and great valley plains; and with respect to period, to be classified under three rather than two distinct seasons, excepting indeed in Upper Assam, where the normal monsoons prevail. Thus in the cold weather months (November to January), the winds are light or completely calm, and the air flows in a gentle current from the plains of Upper India and the Punjab down the valleys of the Indus and the Ganges, or across the hilly water-shed of Central India to join the north-east or east monsoon of the peninsula proper. This appears to have a distinct source in the hill region of Chota Nagpore and the country south of the Satpooras. It is possible that in Upper Assam and in the Upper Punjab, at the two extremities of the Himalaya, some portion of the cool air from the trans-montane region may find egress to the southward; but if so, the amount must be small, and the mountain barrier of the Himalaya, which throughout the interval of 1,500 miles extends unbroken along the northern margin of our area, completely secludes India from the influence of more northern regions.‡ I have not

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\* Physical Geography of the Sea, &c., 12th edition, p. 368.

† See *postea*, Part II, p. 46-47.

‡ In the report on the meteorology for Bengal for 1871, page 122, I wrote otherwise, having been misled by the apparent steadiness of the winds in the Punjab and Upper Assam. Further information on this point, and a consideration of the rainfall distribution, which in the cold weather months seems incompatible with the existence of dry currents from the Tibetan regions, have induced me to modify the views then expressed.

included in the foregoing discussion the wind registers of any Himalayan stations. A detailed analysis, such as I have attempted for those of the low country stations, would in their case only mislead; since at all such stations local influences are so powerful as in a great measure to obscure the effects of such as are more general, and with which alone I am now dealing. But I may observe that at Darjeeling (7,000 feet), even in the cold weather months, southerly elements of wind direction predominate over northerly;\* and according to Dr. Hooker's observations, at great heights in the interior of Sikkim a southerly current prevails throughout the year. At the stations of Chuckrata and Nynsee Tal in the north-west Himalaya, at about the same elevation as Darjeeling, Dr. Murray Thomson's registers show that the winds are almost exclusively from the south or some southerly quarter at all seasons of the year. In Lower Bengal south and south-east winds are not very common from November to January, but their representatives (*viz.* easterly winds,) are more common in Upper India, specially in proportion to winds from the opposite quarters, calms being most frequent of all. I have already mentioned that these easterly winds bring the winter rains, and it will presently be shown that the latter are more regular and copious in the Punjab and upper part of the Ganges valley than in Lower Bengal. From these facts we must, I think, conclude that a portion of the upper or anti-monsoon current, following the same course in the upper atmosphere as the summer monsoon does in the lower, descends on the plains of Upper India, while another portion impinges on the southern slopes of the Himalaya, or even crosses them into Tibet. In the narrower valley of Upper Assam, at least at Sebsaugor, this current appears to be less felt, and winds from north and east blow steadily and persistently; but the omission of the observer at this station to record calms, and the frequent occurrence of rain in the winter months, lead me to doubt whether the effects of the return current are not felt to a great extent in that region also.

With the advent of the hot weather, the winds of Northern India draw round to the westward, and dry currents, partly perhaps derived from the mountainous and desert country lying to the west of the Indus, radiate out over the whole region as far eastward as the eastern limits of the Gangetic delta, and becoming heated in their passage over the plains, form the well known hot winds of April and May. These winds, however, are not steady, continuous currents. They are, as Dr. Hooker has described them, essentially *diurnal* winds, due to the local heating of the soil. They set in about 10 o'clock in the day and blow sometimes in gusts, but in general with tolerable steadiness till sun-down, when they are followed by a calm. On the coast of Orissa, and in the delta of the Ganges, sea winds begin to prevail, however, as early as February,—first on the coast line and in the immediate neighbourhood of the hills, and afterwards more inland. Thus they gradually encroach upon and

\* See the Reports of the Meteorological Department of Bengal, 1869-71. The prevailing directions are east and west, that is, parallel to the great Rungeet valley below the observatory ridge.

eventually displace the land winds<sup>#</sup> near the ground surface, so that in April and May the opposing currents meet obliquely in the hilly region that lies to the west of the delta and of the plains of Orissa. Here at least is their average line of meeting; in March the winds of the delta are nearly as much from west as south, while in May westerly elements preponderate but slightly over easterly at Hazareebagh and even at Benares. The gradual retrograde rotation exhibited by the wind resultants of the Lower Bengal stations in the spring months, is due to the increasing displacement of north-west or land winds by those from the sea, and the latter advance further and further inland, coalescing with the southerly and easterly currents of the Himalayan slopes, and in Behar curving round and blowing as north-easterly winds at Patna and Benares. In Eastern Bengal in like manner they blow up to the Garo and Khasi Hills, where they meet the north-east current from Upper Assam; while in Lower Assam a portion of the latter turns with the valley and blowing steadily from the eastward, probably coalesces with the south-easterly current from the delta. At sea, as Captain Maury has shown, and as further appears from the registers of Chittagong and Akyab, southerly winds gain possession of the Bay by a like gradual extension southwards from the coast line of the delta. They back down, as Captain Maury expresses it, about  $5^{\circ}$  or  $6^{\circ}$  of latitude on an average between February and March, but less rapidly on the Arakan coast than on that of India. Thus at Madras, in latitude  $12^{\circ}$ , southerly winds predominate in March; whereas at Akyab, in latitude  $20^{\circ}$ , they do not gain the upper hand until the month of May. A section of the atmosphere from Upper Assam to the Bay near the Arakan shore in the latitude of Akyab, would probably in the month of March present a system of currents somewhat resembling the accompanying diagram (Fig. 1).

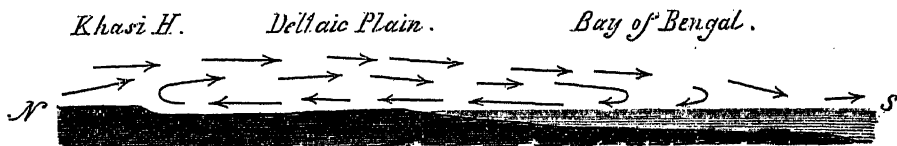


Fig 1.

In Western India, in Sind, and the desert of Bikaner, southerly winds prevail in like manner in the spring months, and penetrate inland as far as Mooltan and Ajmere. At the latter station, situated at nearly 2,000 feet above the sea, they predominate as early as February, while at the former they do not exceed northerly winds until May. At Agra they are felt in April, but do not preponderate.

In June the south-west monsoon sets in on both coasts of the peninsula. The current from the Arabian Sea, sweeping across the Sahyadree Mountains and up the valleys of the Taptā and Nerbudda, blows as a west or west-south-west current over Central India up to the very confines of the Gangetic plains, and across the peninsular south of the Satpooras up to the coasts of Orissa. That from the Bay of Bengal pours into the funnel-shaped opening occupied by the delta, and then, turning westward, passes up the Ganges valley towards the Punjab; while upper currents sweep

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\* In this place and throughout this paper, I use the terms 'land-winds' and 'sea-winds' to designate winds which originate respectively in the interior or at sea, without regard to their periodicity, whether it be annual or diurnal.

over the Hazareebagh plateau in the same direction, and across the hills of Eastern Bengal towards the valley of Assam and the river gorges that afford them an entrance to Tibet. It is not improbable that a portion of the current that traverses the Bundelkund plateau from the Arabian Sea may, on reaching the Gangetic plain, curve round towards the north-west as an upper current, coalescing with that from the Bay of Bengal. But no such passage can be detected in the registers of the surface winds. Indeed along the southern margin of the plain the winds are on the whole rather from north-east, blowing towards the Malwa and Bundelkund plateau during the height of the monsoon. In any case the Punjab is the limit of these winds. On reaching the plain of the five rivers they perform a kind of cyclonic circulation around it, and in Affghanistan, although easterly winds are occasionally felt at this season, the dominant current is from the westward.

Up to the close of the south-west monsoon in October, the Coromandel Coast and the plains of the Carnatic have received but little rain, and remain at a higher temperature than any other part of the peninsula. Unsteady north-east winds, alternating with calms and variable winds from other quarters, then set in on the Orissa Coast and over the north-west part of the Bay ; while the southerly current recurves from south-east and blows towards this heated region, bringing the late autumn rains, which some writers have erroneously attributed to the north-east monsoon.\* At the same time the winds of Lower Bengal are conflicting and variable, and calms (alternating with storms) are at their maximum frequency. But in the North-Western Provinces, where the rains cease somewhat earlier and the temperature falls more rapidly, there is during the greater part of October a decided movement of the air from the west and north-west. In like manner in the Central Provinces light land winds have set in from east and north-east, which latter (or east to the south of the Satpooras) is there the characteristic direction of the winter monsoon. It is not until the end of this month, or in November, that north-west winds blow over the delta, connecting the north-west current of Upper India with the north-east winds of the northern part of the Bay in a continuous stream, and that it can therefore be said with strictness that the north-east monsoon has set in.

The manner in which the change of monsoons takes place in the Bay of Bengal has been already described by Captain Maury in the following terms:—"In October the north-east trades lead off the attack, and the two combatants have force enough about the parallel of  $15^{\circ}$  N. to blow during this month nine days each. The conflict, instead of being back to back, is now face to face ; instead of blowing away from the medial line (as in March), they now blow towards it ; instead of being a place of high, the medial line is now a place of low barometer. By November the north-east trade has pushed the place of equal contest as far down as the parallel of  $5^{\circ}$  N." With some demur to certain expressions, which might be taken to imply

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\* This error was distinctly pointed out by Professor Dove in his Treatise "Ueber die Vertheilung des Regens auf der Oberfläche der Erde," page 98.

that the winds are impelled towards their place of meeting against mutual resistance by a *vis a tergo*, the above represents in a general way the character of the north-east monsoon's advance. But, as in the case of the opposite change already described, this advance is more rapid on the Indian than the Burmese coast of the Bay. At Akyab southerly winds still preponderate in October, while at False Point north and north-east winds are in considerable excess, and even at Madras northerly winds are quite as frequent as those from southerly quarters in that month.

Such being the general scheme of the wind currents of Northern India, it remains now to trace out their relations to temperature, humidity, and atmospheric pressure at the different seasons of the year. With this view I proceed to give a sketch—imperfect indeed in many respects, but still not without value—of the distribution and annual changes of these important elements of climate.

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## PART II.

### RELATIONS OF THE WINDS TO OTHER ELEMENTS OF CLIMATE.

*Temperature.*—The general distribution of temperature, which I have deduced from the registers of the last few years,\* agrees generally with that represented on the Messrs. Schlagintweit's charts in the 153rd volume of the Philosophical Transactions. But the Messrs. Schlagintweit's division of the year into four equal periods does not admit of the phenomena being represented in sufficient detail for the present purpose; nor does it accord with the natural arrangement of the seasons, which in Northern India present only three distinct phases. These are—(i) the *cold season*, lasting from the breaking up of the rains, in October, to February or March; (ii) the *hot season*, characterized in general by a dry atmosphere and a great diurnal range of temperature; and (iii) the *rainy season*, in which the temperature is moderately high and equable, and the air very humid. The beginning and ending of these seasons differ in period somewhat in different parts of the area, and the gradations of temperature which accompany them are very different both in period and amount. In describing these latter it will be convenient to take the month of October as our starting point. Except where otherwise specified, the figures quoted in the following description of the horizontal distribution of temperature, are those of Table III, viz. the *sea-level equivalents* of the observed mean temperatures.

At the close of the rains, in the early part of October (Pl. V), the temperature of Northern India is nearly uniform at about  $81^{\circ}$  or  $82^{\circ}$ . But changes soon set in: evaporation and radiation to a cloudless sky speedily reduce the temperature of the more elevated plains of the interior below that of the maritime belt; and thus the average temperatures of the whole month, given in Table III, show an extreme variation of  $8^{\circ}$ . In the two following months the inequalities thus arising become greatly intensified; and they culminate in January, when there is a difference of nearly  $20^{\circ}$  between Mooltan and Bombay. The distribution of temperature

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\* I give the results in two tables—the first of which shows the mean temperature of each place in each month of the year, as deduced from the observations, the second the equivalents of these at sea level. The means have been obtained in various ways. For the Lower Provinces and Assam, as well as for Roorkee and (in part) Benares, I have taken the arithmetical means of observations recorded at 4 and 10 A.M. and P.M. In the case of Seesaugor alone, sunrise observations are substituted for those at 4 A.M. At stations in the Central and North-Western Provinces (other than Roorkee and Benares), the mean of the minimum and 4 P.M. temperatures is taken as the mean of the day; and in the case of the Punjab stations, I have applied to the means of the mean maxima and minima, a correction, proportional to the mean diurnal range, derived from the Roorkee registers. The sea level values in Table III are obtained by adding to the figures in Table II,  $1^{\circ}$  for every 350 feet of elevation.

Owing to the shortness of the periods from which in many cases the mean temperatures of Tables II and III have been obtained, the diversity of the methods of reduction, and, above all, my uncertainty how far the instruments employed in the Central Provinces, the North-Western Provinces, and the Punjab, can be accepted as accurate and comparable, I hesitate to base any conclusions on small differences of temperature, even when the registers of several stations yield concordant evidence of

in this month is shown in the chart (Pl. I), on which the isotherms are interpolated from the figures given in Table III, with some additions in particular cases. Without insisting on small differences, which may be subject to correction on the review of a longer period and with more accurate coefficients of the temperature correction for altitude, it is clear that the Punjab is in January the seat of the greatest cold, while Rajpootana, on the one hand, and the Gangetic delta and Lower Assam on the other, are warmer than the regions immediately adjacent under the same latitudes. The difference of the mean temperature of the Punjab stations ( $55^{\circ}$ ) and that of Calcutta, Berhampore, and Goalpara ( $66^{\circ}$ ), is not less than  $11^{\circ}$ . The great Gangetic plain, lying between them, enjoys a nearly equable temperature throughout of  $60^{\circ}$  or a little under. Benares in this month appears to have a lower temperature (for its elevation) than Roorkee, and very much lower than Goalpara, both in higher latitudes. Opposite to the Gulf of Cambay and the Bay of Bengal, especially the latter, the isotherms advance northwards, retreating again to the south in a festoon-shaped curve in the interval, so that Benares and neighbouring stations in the Gangetic plain enjoy a lower temperature than any other part of India under the same latitude. In the peninsular south of the Satpooras the isotherms appear to be more regular, but the data available for this region are as yet insufficient to show their course with any pretence to accuracy.

In February and March (Pls. I and II) a general rise of temperature is accompanied by important modifications in its relative distribution. The isotherm of  $70^{\circ}$ , which in January ran across the peninsular south of the Satpooras, is now (in March) pushed up to the Punjab, indicating a general average rise of  $10^{\circ}$ . The greatest rise is at Benares and Patna ( $16^{\circ}$ ), the least at Bombay ( $4.3^{\circ}$ ), and two thermal foci begin to make their appearance in the Central Provinces and the hilly country of Western Bengal. The temperature difference of Rawul Pindee (the coldest station of the Punjab) and Calcutta, is  $15^{\circ}$ ; that of Rawul Pindee and Nagpore,  $19^{\circ}$ .

In April (Pl. II) the thermal focus of Central India is well developed. The mean temperature of Nagpore in this month is  $7^{\circ}$  above that of Bombay (allowing for altitude),  $13\frac{1}{2}^{\circ}$  above that of Rawul Pindee, and  $6^{\circ}$  above that of False Point.

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their reality. For these reasons I am far from confident that the peculiar loop which the isotherm of  $60^{\circ}$  makes in the Gangetic plain in the January chart will be substantiated by more complete and trustworthy data. Its existence rests on the evidence of Benares and Lucknow given in the tables, with that of Bareilly, Goruckpore, and Fyzabad (each for four years). The January temperatures of these latter stations are respectively  $57.4^{\circ}$ ,  $60.1^{\circ}$ , and  $60.5^{\circ}$ , which, reduced to sea level values, are  $59^{\circ}$ ,  $60.8^{\circ}$ , and  $61.5^{\circ}$ . There are, however, independent grounds for regarding as probable the distribution of temperature thus indicated. There is an evident relation between the loop of abnormally low temperature and that of high pressure shown in the same chart; and the fact already noticed, that southerly winds prevail on the southern slopes of the Himalaya throughout the cold weather months, might lead us to anticipate a somewhat higher temperature in the neighbourhood of the hills, where, as I suppose, the anti-monsoon current descends to a lower level than further south. It is true that the isotherm of  $65^{\circ}$ , as laid down on the chart, shows no corresponding loop where it might be expected to occur; but I have no observations for determining this part of its course nearer than Hazareebagh, which is at an altitude of 2,000 feet.

The region of greatest heat is indicated on the chart (Plate II) by the isotherm of  $90^{\circ}$ , which includes the stations of Nagpore and Hoshungabad. The whole of Central India with Rajpootana, Bundelkund, and Behar, Western Bengal south of the Ganges, with Chota Nagpore and Orissa, have a mean temperature between  $85^{\circ}$  and  $90^{\circ}$ . The Upper Punjab (including Rawul Pindee) and Upper Assam are the coolest parts of our region, having a mean temperature of  $75^{\circ}$  to  $77^{\circ}$ .

In May (Pl. III) the thermal focus moves up somewhat to the north-west, Ajmere and Jhansi being now the hottest stations in the list, while the isotherm of  $95^{\circ}$  embraces nearly the whole of the Malwa plateau together with the region lying around Nagpore. But the rise of temperature in the Punjab is greater than in Rajpootana. At Ajmere and Jhansi the mean May temperature is  $8^{\circ}$  and  $9^{\circ}$  higher than that of April, but at Mooltan it is  $10^{\circ}$ , at Lahore  $11^{\circ}$ , and at Rawul Pindee, the most northerly station, nearly  $14^{\circ}$ . In Upper Assam there is a rise of  $6^{\circ}$  or  $7^{\circ}$ , but Lower Assam remains cool; the May temperature of Goalpara being only  $1^{\circ}$  above that of April. The mean temperature of the Assam valley in this month is about  $80^{\circ}$ , that of the Punjab  $91^{\circ}$ .

In June (Pl. III) the focus of heat has travelled up to the Punjab, the temperature of which has risen from  $3^{\circ}$  to  $7^{\circ}$  above that of May, while at Nagpore it has fallen  $8^{\circ}$  in consequence of the cooling effect of the summer rains. The rains do not set in on an average till the middle of the month, so that the decrease of the June mean temperature from that of May is not more than about half the whole reduction produced by the monsoon rains. To the north of the Satpoooras and to the west of the Hazareebagh plateau, where the rains do not set in till the end of June or the beginning of July, the mean temperature of June is equal or nearly so to that of May; while in the Punjab (as above mentioned,) there is a rise of  $3^{\circ}$  to  $7^{\circ}$ , and in Upper Assam, where heavy rain falls from March or April, a rise of nearly  $4^{\circ}$ .

In Upper Assam indeed all the seasons are less strongly characterised than in Northern India. Here, as in the temperate zone, the heat increases gradually and uniformly up to July, and from June to September remains about  $4^{\circ}$  above that of the delta. Even at Goalpara, at the mouth of the valley, no fall of temperature results from the burst of the monsoon rains, but a steady rise of  $1^{\circ}$  per month after April brings the mean temperature up to between  $82^{\circ}$  and  $83^{\circ}$  in July and August, and is followed by an equally steady fall till October. In Assam the hot season, as understood in Northern India, is unknown.

The progressive fall of temperature in Northern India, as the monsoon rains advance, on the one hand, from the Arabian Sea, and on the other from the Bay of Bengal, is very clearly shown in the chart for July (Pl. IV). The greater part of Central India and the whole of the Lower Provinces, together with Lower Assam and Cachar, have now a mean temperature below  $85^{\circ}$ . But the Punjab and the Bikaneer desert still range above  $90^{\circ}$ . The highest temperature is that of Rawul Pindee, where the fall from June amounts only to  $2\frac{1}{2}^{\circ}$ .

From July to October (Pls. IV and V) the temperature gradually declines, in such measure that by the end of September or the beginning of October it is nearly equalized over Northern India. In the Central Provinces indeed, and in Rajpootana, also at Calcutta and some other stations in Bengal, there is a slight rise of temperature in September just before the rapid fall sets in.

To sum up the above facts briefly. The distribution of temperature in Northern India presents three very distinct phases, corresponding to the three seasons already defined. In the cold weather two loci of minimum temperature are situated in the Punjab and Upper Assam, and there is a secondary locus of abnormally low temperature, extending apparently from Bareilly to Benares. With this exception the general course of the isothermals conforms more nearly to the parallels of latitude than at any other season.

In the hot weather a temperature focus is found in Central India, and the uplands and plateaux south of the Ganges and eastward from the Sahyadree Mountains have a temperature considerably higher than that of the Gangetic plain, the maritime belt or the surrounding seas. The Upper Punjab and Upper Assam are still the coolest parts of our area.

Finally, in the rains, the Punjab is the seat of the highest temperature, and Upper Assam, though much lower, nevertheless ranges above Bengal. The coolest regions are those where the rains are most copious, and consist of two tracts extending inland from the coasts of Bombay and Bengal respectively, in the course of the monsoon currents.

To complete this discussion, it remains to consider the distribution of temperature in a vertical direction at different seasons of the year. The only available evidence bearing on this subject is that afforded by the hill stations, of which the best are Darjeeling, at 6,941 feet, with Goalpara 386 feet, as a reference station, and Chuckrata at 6,884 feet, which may be compared with Roorkee at 880 feet; the former illustrating the damp climate of Bengal, the latter the drier and more continental climate of Upper India. Shillong, being situated on a plateau, is less favourable for the purpose, but may be adduced as an additional example of a Bengal station at a lower altitude (4,792 feet), and can be compared with Goalpara on the north-west and Silchar (75 feet) on the south-east. Lastly, I shall give a comparison between Nynsee Tal at 6,400 feet, and Roorkee, observing, however, that the situation of the former station, on the banks of a mountain lake in a hollow valley, is such as to impair its character as a representative station. These data are given in the following table.

*Table of comparative temperatures at four hill stations and three stations on the plains, showing the variations of the temperature decrement with altitude in each month.*

	Darjeeling, 6,941 ft.	Goalpara, 386 ft.	Difference G—D.	Elevation = 1 ° Fahr.	Shillong, 4,792 ft.	Goalpara, 386 ft.	Difference G—S.	Elevation = 1 ° Fahr.	Silchar, 75 ft.	Difference SI—Shil.	Elevation = 1 ° Fahr.	Elevation mean of cols. 8 and 11.
	°	°	°	ft.	°	°	°	ft.	°	°	ft.	ft
January ... ..	42·9	64·3	21·4	301	51·3	64·3	13	339	64·4	13·1	360	360
February... ..	44·5	67·4	22·9	286	54·2	67·4	13·2	333	68·2	14	337	335
March ... ..	50·4	73	22·6	290	61·4	73	11·6	380	74·5	13·1	360	370
April ... ..	56·1	77·1	21	312	64·5	77·1	12·6	350	78·2	13·7	344	347
May... ..	60·2	78·2	18	363	68·4	78·2	11·8	373	81·1	12·7	371	372
June ... ..	63·3	79·9	16·6	395	69·4	79·9	10·5	420	81·9	12·5	377	399
July... ..	63·9	81	17·1	383	69·6	81	11·4	386	82·1	12·5	377	382
August ... ..	64	81·3	17·3	379	69·2	81·3	12·1	364	81·6	12·4	380	372
September ... ..	62·1	80	17·9	366	67·3	80	12·7	347	81·4	14·1	334	341
October ... ..	58	78·3	20·3	322	63·5	78·3	14·8	300	79·8	16·3	289	295
November ... ..	50·2	71·1	20·9	313	56	71·1	15·1	292	72·1	16·1	292	292
December... ..	44	64·8	20·8	315	50·1	64·8	14·7	300	65	14·9	317	309
Year... ..	55	74·7	19·7	335	62·1	74·7	12·8	349	75·9	13·8	345	347
Range ... ..	21·1	17·0	6·3	109	19·5	17	4·6	128	17·7	3·9	91	107

	Chackrata, 6,884 ft.	Roorkee, 880 ft.	Difference R—C.	Elevation = 1 ° Fahr.	Nynce Tal, 6,400 ft.	Roorkee, 880 ft.	Difference R—N.	Elevation = 1 ° Fahr.
	°	°	°	ft.	°	°	°	ft.
January ... ..	42·6	57·6	15	400	43·8	57·6	13·8	400
February ... ..	44·5	62·3	17·8	337	43·3	62·3	19	291
March ... ..	50·2	69·6	19·4	309	51	69·6	18·6	297
April ... ..	59·5	80·4	20·9	287	60	80·4	20·4	271
May ... ..	68·7	88·6	19·9	302	66	88·6	22·6	244
June ... ..	69·5	89	19·5	308	69	89	20	276
July ... ..	65·7	84·5	18·8	319	68·7	84·5	15·8	349
August ... ..	65·1	84·2	19·1	314	68	84·2	16·2	341
September ... ..	62·2	83	20·8	288	66·3	83	16·7	330
October ... ..	59·2	76	26·8	224	58·7	76	17·3	319
November ... ..	53·5	63·7	20·2	297	50	63·7	13·7	403
December ... ..	44·2	57·5	13·3	451	45·7	57·5	11·8	468
Year ... ..	57·1	74·7	19·3	320	57·5	74·7	17·2	332
Range ... ..	28·9	31·5	13·5	227	25·7	31·5	10·8	224

The average of the three tables of the Bengal stations gives a mean increment of 343 feet elevation for each temperature decrement of  $1^{\circ}$  Fahr. In the North-West Himalaya the temperature decrease would appear to be on the whole more rapid, the average of the two tables being 326 feet per  $1^{\circ}$ . But these are only the mean results of the year, and the tables show a wide departure from this average in different months of the year, which is least at Darjeeling, greatest at Chuckrata. The difference of temperature between this latter station and Roorkee in October is more than twice as great as in December.

At Darjeeling the decrease of temperature with elevation is most rapid in February. This is not indeed the coldest month at Darjeeling; but in the first two months of the year the temperature rises less than at Goalpara. Between February and June, on the other hand, the rise is greater at the hill station, especially in the month of May; and about the time when the rains set in generally over Bengal, the difference of temperature between Darjeeling and Goalpara is less than at any other time of the year. The difference increases during the rains, but only to the extent of  $1.1^{\circ}$ . On their cessation in October, a sudden increase of  $2.4^{\circ}$  takes place, and the difference is further augmented by  $2.6^{\circ}$  up to the month of February.

At Chuckrata the difference from Roorkee is greatest in October and least in December. From this month it increases rapidly till April, after which there is a slight fall till July, followed by a rise which is extremely rapid at the close of the rains up to the maximum in October. At Nynsee Tal the variations are similar, except that the first and absolute maximum difference occurs in May, and the increase at the close of the rains is comparatively small in amount.

It would lead me into a lengthy digression, unnecessary to my present purpose, to enter on a detailed discussion of the extremely complicated causes which give rise to these irregularities in the vertical distribution of temperature in the lower atmosphere; and indeed I am doubtful whether with our present data a very satisfactory result could be looked for. An investigation of similar phenomena in the case of Hoch Obir, compared with Klagenfurt and other stations in Carinthia by M. J. Hann, has led him to some general conclusions, which I quote below,\* and which seem to help

\* The problem which M. Hann desired to solve in this inquiry was the relation of the temperature decrement with altitude to the wind direction; and he expresses his results in the following empirical laws:—

1. "Die Temperaturabnahme nach oben ist bei südlichen und südwestlichen Winden langsamer als bei nördlichen und nordöstlichen.

\* \* \* \* \*

2. "Die Temperaturabnahme mit der Höhe zeigt eine grosse Abhängigkeit von der Windstärke—sie ist stets grösser bei Stürmen, aus welcher Richtung sie auch kommen mögen; aber auch der Unterschied zwischen nördlichen und südlichen Strömen spricht sich dann noch schärfer aus. Die Ursache davon liegt, wie noch gezeigt werden soll, zumeist in dem raschen gezwungenen Emporsteigen der Luft.

3. "Bei schwachen Winden und heiterer Witterung ist die Temperaturabnahme in den unteren Schichten sehr verzögert; sie wächst aber dann rascher in den höheren Luftschichten. Die Temperaturverminderung mit der Höhe ist am langsamsten bei heiterer Witterung und schwachen Westlichen Strömungen in die Höhe."

to an explanation of the present case; but the climatal conditions of an European hill tract are so different from those of the Gangetic plain and the Himalayan boundary chain, that conformity of the local empirical laws of the two regions is not to be expected. M. Hann has not suggested any physical cause for the difference he has observed in the temperature decrements with south-west and north-east winds, and I may therefore be permitted to suggest one in the difference of their humidity; since the continual upward diffusion and condensation of water vapour must tend to equalize the temperatures of the lower and higher strata, and this tendency will be the greater the higher the humidity of the air, that is, the nearer it is to saturation. In the case of the Himalayan stations there appears to be a certain inverse ratio between the relative humidity of the atmosphere and the difference of temperature at the upper and lower stations—not indeed such as to explain the whole of the variation, but such as to indicate that the condensation of vapour exercises an important influence on the phenomenon. This is shown in the accompanying diagrams (Figs. 2 and 3), which give

Fig. 2.

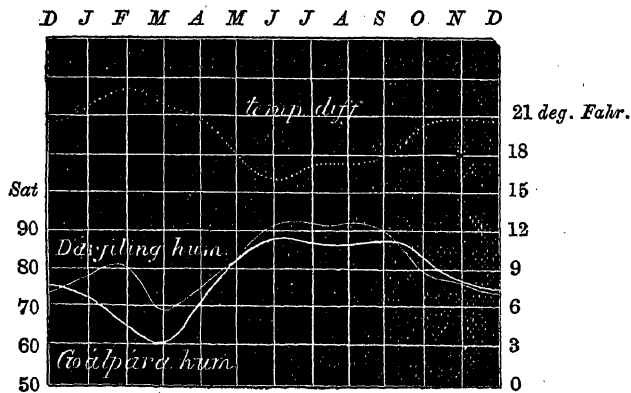
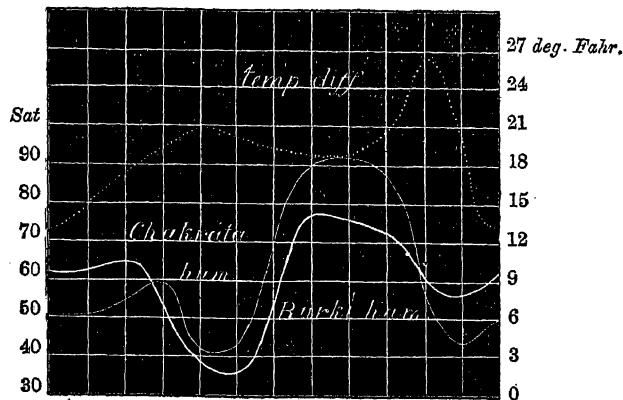


Fig. 3.



the curves of mean humidity at two of the higher and two lower stations, together with those of the temperature differences between the pair of stations contrasted.

It will be observed that in the case of the damp climate of the Sikkim Himalaya, the temperature-difference curve is considerably less irregular than in the dry climate of the North-Western Provinces, and that the absolute minimum difference at Darjeeling and the secondary minimum at Chuckrata coincide with the high humidity of the rains. Further, that the rise of temperature over the plains in the early months of the year is felt at Darjeeling two months earlier than at Chuckrata; and the rise of temperature at the former between March and June, which much exceeds that at the lower station of Goalpara, (reducing their difference), and which I suppose to be due to the condensation of moisture as cloud and rain in those months, is but faintly indicated, and at a later season at Chuckrata, where the rainfall is small at that period of the year. (*See the rainfall table at the end*).\* One very important datum is yet wanting for the north-western hill stations, viz. the proportion of cloud-obscuration; and the radiation observations are imperfect. At Roorkee the sky is more free from cloud in October than in any other month of the year, and the same is probably the case at Chuckrata. If so, the great difference of temperature in this month may be due to the increased radiation at the upper station. It is to be hoped that in the course of a few years data will be collected that will admit of a more satisfactory investigation of the subject.†

\* The rainfall tables for Nynee Tal and Simla may be taken as illustrations of the rainfall of the North-West Himalaya in lieu of that of Chuckrata, of which I have the record for only two years.

† The registers of the temperature of nocturnal radiation at the hill stations of the North-Western Provinces are at present imperfect, and there appears to be a peculiar difficulty in obtaining observations at such stations, that shall be comparable with those on plains' stations, owing to the convection of the cooled air on sloping ground. It may be therefore, and probably is the case, that the recorded temperatures of radiation at night are much above those that would be given by an instrument placed in a hollow. I find in Dr. Thomson's reports, one year's observations at Nynee Tal, 10 months' at Raneekhet, near Nynee Tal, and 7 months' at Chuckrata. The following table gives in one column the means of all these (without distinction of station), in another those of the same years at Roorkee, and in a third the difference of the two. The remaining columns show the mean maximum temperatures of solar radiation for the same years treated in like manner, and their differences.

	GRASS NOCTURNAL RADIATION.			SOLAR RADIATION.		
	Hill stations.	Roorkee.	Difference R—H.	Hill stations.	Roorkee.	Difference R.—H.
January ... ..	27·3	40	12·7	85·2	110	24·8
February ... ..	28·6	41·5	12·9	90·3	114·5	24·2
March ... ..	38·5	51·5	13	113	128	15
April ... ..	43·6	60	16·4	119·3	129	9·7
May ... ..	50·3	67	16·7	121·7	143·5	21·8
June ... ..	53	74·5	21·5	121·3	139·5	18·2
July ... ..	52·5	78	13·5	114·7	133	18·3
August ... ..	54	75	21	115·3	127	11·7
September ... ..	51	72	21	123·4	127·9	4·5
October ... ..	38·8	58·8	16	123·3	127·8	4·5
November ... ..	34·5	43·1	18·6	114·5	121·1	6·6
December ... ..	28·9	38	9·1	97·5	109·7	21·2

From this rough comparison it would seem that the excess of nocturnal radiation at the hill stations in October is not so great as in the rainy months, and so far the fall of temperature in that and the preceding month, as compared with Roorkee, remains unexplained. But it also appears that the solar heat is at all times (on an average) less intense than on the plains, and that this difference is least in September and October. It would appear then that on an average less solar heat reaches the hill surface at these stations, 7,000 or 8,000 feet above sea level, than the surface of the plains immediately below the hills. The figures are far from accounting for the observed variation of temperature-difference.

On the low plateaux to the south of the Ganges, and in the higher parts of the Gangetic plains, the distribution of temperature follows laws very different to the above. In their case a moderate elevation appears to determine an increase of the summer temperature and a decrease only in the winter season, or, in certain cases, in the rains, consequently an increased annual range. Whether the mean temperature of the year shows a diminution corresponding to the altitude above sea level, cannot very well be ascertained in the case of stations on the Gangetic plain, because their distance from stations of reference at or near the sea level is so great that it is impossible to eliminate the effects of other geographical differences, such as the slope of the ground, proximity of hills or water, &c., and I have already remarked that many of the registers are not, in my opinion, strictly comparable for small differences. But in the case of the somewhat more elevated plateaux, we have more trustworthy means of comparison in the stations of Hazareebagh and Berhampore, situated under nearly the same latitude, about equally distant from the sea, and affording observations with corrected thermometers, observed four times a day, at equal intervals of six hours. Moreover, their registers extend over the same period of the four years 1868-71. Finally, their geographical *entourage* is such as to offer no striking contrasts, except *that* the effect of which is in question ; since Berhampore is on a comparatively dry part of the delta, and at no great distance from its margin. Hazareebagh is situated at 2,014 and Berhampore at 65 feet above the sea level. The following table gives the mean temperature of each station and their difference in each month :—

*Table of comparative temperatures at stations on a plateau and in the plains, showing the temperature difference in each month.*

	Hazareebagh, 2,014 feet.	Berhampore, 65 feet.	Difference B—H.
	°	°	°
January ... ..	61·7	65·3	3·6
February ... ..	66·2	70·7	4·5
March ... ..	74·8	78·2	3·9
April ... ..	82·6	85·5	2·9
May ... ..	85·9	86·3	0·4
June ... ..	81·4	84·6	3·2
July ... ..	79·2	84	4·8
August ... ..	77·9	84·1	6·2
September ... ..	77·3	83·4	6·1
October ... ..	74·5	81·7	7·2
November ... ..	68·9	73·5	4·6
December ... ..	61·6	66·2	4·6
Year ... ..	74·3	78·6	4·3
Range ... ..	24·3	21	6·8

On the average of the whole year, Hazareebagh is then 4·3° cooler than Berhampore ; which, for a difference of 1,949 feet, gives a mean of 1° Fahr. for 453 feet.

The temperature difference is least in May, when it amounts to only  $0\cdot4^{\circ}$ , but Hazareebagh is still the cooler, and this station is therefore above the range at which elevation produces an actual increase of summer temperature. The difference is greatest in October; but from July to December it remains above the average of the year, and thus (in respect of the rainy season) contrasts strongly with the corresponding variation at hill stations. The variation may, I think, be traced partly to the character of the winds, but chiefly to the local absorption and radiation of the solar heat. In May there is at Berhampore, as at all stations on the delta, a very large excess of south and east, that is ~~the~~ say sea-winds, more or less deflected; while at Hazareebagh there is still an excess of west and a large proportion of north-west, that is hot land winds. In October the preponderance of sea and land winds respectively at the two stations is similar, but the land winds are at this season of the year the cooler of the two. But a further and more important cause tending to produce the observed variation is the difference of nocturnal radiation and diurnal absorption of solar heat in those months. This difference is at its minimum in May, and its maximum in October in the former case, and *vice versa* in the latter. The mean of three years' observations of a Rutherford's minimum thermometer (placed above the ends of the grass on forked sticks) and radiating its heat freely during the night time, is as follows:—

		Hazareebagh.	Berhampore.	Diff. B—H.
May	...	72·2°	73·5°	1·3°
October	...	59·8°	71·8°	12·0°

On the other hand the mean of three years' observations of a maximum blackened-bulb thermometer enclosed in a vacuum tube, and freely exposed to the sun, the observations having been recorded on all days, whether clear or overcast, is as follows:—

		Hazareebagh.	Berhampore.	Diff. H—B.
May	...	160·5	150·8	9·7
October	...	140·3	142·7	—2·4

A similar excess of nocturnal radiation and decrease of insolation, but less in amount, characterises the rainy months at Hazareebagh, and serves to explain the lower temperature of that station. I need not pursue this subject further at present. The important point which is so strongly indicated by the above facts, is that the temperature of the atmosphere over the plateau is largely affected by the absorption and radiation of the ground, and therefore does not represent that of the free atmosphere at an equal height over the plains. Any difference of temperature thus arising between two masses of air in the same horizontal plane must tend to produce convection currents; and of such currents tending to or from the plateaux of Central and Upper India and Western Bengal, we have many instances.

*Vapour tension, humidity, and rainfall.*—The existing records of the hygrometric state of the atmosphere, from which I have constructed Tables IV and V, are less

complete than could be desired. With the exception of the Lower Provinces and Bombay (Colaba Observatory) and two stations in the North-Western Provinces, the available humidity registers give observations of the day hours only; and in order to obtain comparable values, I have multiplied these by factors obtained empirically from the registers of Benares and Roorkee (*see note to Table V*). I have rejected the data of several stations which it would have been desirable to add, since they give results so much above other stations similarly situated, as to leave me in little doubt of their untrustworthiness. The table of vapour elasticities is computed directly from those of the mean humidity and the mean temperature, except in the cases of Calcutta and Bombay, where the figures have been obtained from the psychrometer observations taken hourly and reduced for each observation. With these two exceptions the values are therefore in all cases somewhat too low.

Since, as is well known, Northern India with Eastern Bengal presents in different parts the extreme modifications of continental and maritime climate, it might be expected that the range of vapour tensions shown by a comparison of the registers would be very great; and such is indeed the case. The extreme amounts shown in the present table are furnished by Mooltan and False Point; the annual mean of the former being 0.382 inches, while that of the latter is 0.862 inches.\*

But this, the geographical range, is in certain cases surpassed by the annual range at one and the same station. Of this the stations in the Gangetic plain offer the most striking examples. Thus at Patna the mean vapour tension rises from 0.328 in January to 0.969 in July, at Benares from 0.325 in December to 0.977 in July, and at Roorkee from 0.293 in December to 0.911 in July, the ranges being therefore 0.641, 0.652, and 0.618 respectively. On the other hand Bombay and Akyab, the climates of which are more equable than that of any other station, show a range of 0.335 and 0.374 only.

The lowest vapour tension occurs in January at most of the stations, coinciding with the minimum of temperature. At one or two only it appears to be slightly lower in December. Such is the case at Cuttack, False Point, and Saugor Island, where sea winds set in very early in the year (*see ante*, Part I, pp. 17, 19), and at Benares. Generally in the upper part of the Gangetic plain, in Central India, and the Punjab, the means of December and January are almost equal. In the Gangetic delta and Orissa, on the coast of Arakan, and in Eastern Bengal and Lower Assam,† the elasticity rises regularly and rapidly up to the setting in of the rains, indicating a steady increase in the supply of vapour as well as a rising temperature. But in the dry regions of the interior, where land winds prevail throughout the spring months, the rise of vapour tension is very slow, not much greater probably than would be produced by the actual rise of temperature on the local supply of vapour.

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\* The January mean at the former station is 0.208 inches; the May mean at the latter 1.079 inches.

† Probably also in Upper Assam, but I have no register for that region.

The elevation, when the summer monsoon begins to be felt in June or July, is then very sudden, and the fall at the close of the monsoon between September and November equally strongly marked.

As regards the decrease of vapour tension with elevation above sea level, a comparison of its mean values at Hazareebagh, Shillong, and Darjeeling, with those of neighbouring stations near the sea level, affords additional confirmation of the conclusions drawn by General Strachey\* from the observations of Dr. Hooker in Sikkim and those of Mr. Welsh in England. Comparing in the first place the Darjeeling values with those of Goalpara, it appears that in most months the former are rather more than half as great as the latter, and that the proportions are relatively greater in the months of the rains than in those of the cold or hot seasons. The total atmospheric pressure, however, at the former station is at all seasons more than three-fourths of that at the latter, so that the diminution of atmospheric density over Bengal from January to June, in so far as it is due to the admixture of water vapour, chiefly affects the lower fourth of the atmosphere. Of this additional proofs will appear presently. At Shillong the proportion is somewhat higher, but more constant as compared with the means of Goalpara and Silchar, the same reference stations that have been selected for a comparison of temperatures. But at Hazareebagh, while the mean proportion is higher than either of the above, nearly three-fourths of that on the plains, the range is also greater than either, varying from 59 to 90 per cent. of that at the lower stations. For this station I have taken as a standard of reference the means of Patna and Calcutta conjointly, these stations being alternately to windward and leeward of Hazareebagh at opposite seasons of the year. The results of these several comparisons are shown in the following table:—

*Table of comparative vapour tensions at stations at different elevations, showing the ratios of decrement in each month.*

	Darjeeling, 6,941 ft.	Goalpara, 386 ft.	Ratio D : G.	Shillong, 4,792 ft.	Mean of Goalpara and Silchar.	Ratio $S : \frac{G+S}{2}$	Hazaree- bagh, 2,014 ft.	Mean of Calcutta and Patna.	Ratio $H : \frac{C+P}{2}$
	Inch.	Inch.		Inch.	Inch.		Inch.	Inch.	
January ... ..	0.212	0.439	0.48:1	0.265	0.459	0.58:1	0.280	0.407	0.68:1
February ... ..	0.238	0.435	0.55:1	0.273	0.483	0.56:1	0.284	0.447	0.59:1
March ... ..	0.252	0.487	0.52:1	0.321	0.562	0.57:1	0.330	0.548	0.60:1
April ... ..	0.338	0.632	0.53:1	0.394	0.690	0.57:1	0.423	0.644	0.65:1
May ... ..	0.427	0.790	0.54:1	0.534	0.861	0.63:1	0.557	0.776	0.72:1
June ... ..	0.529	0.897	0.59:1	0.598	0.923	0.64:1	0.796	0.899	0.88:1
July ... ..	0.546	0.919	0.59:1	0.629	0.943	0.66:1	0.867	0.961	0.90:1
August ... ..	0.548	0.916	0.60:1	0.627	0.942	0.66:1	0.812	0.949	0.85:1
September ... ..	0.501	0.900	0.55:1	0.588	0.926	0.63:1	0.786	0.932	0.84:1
October ... ..	0.381	0.732	0.49:1	0.503	0.828	0.63:1	0.563	0.778	0.72:1
November ... ..	0.276	0.593	0.48:1	0.341	0.823	0.55:1	0.360	0.539	0.66:1
December ... ..	0.213	0.459	0.46:1	0.271	0.480	0.56:1	0.279	0.415	0.67:1
Year ... ..	0.388	0.687	0.56:1	0.445	0.728	0.61:1	0.526	0.891	0.76:1
Range ... ..	0.336	0.484	...	0.364	0.487	...	0.603	0.654	...

\* Proc., Royal Soc., Vol. XI, p. 182.

Turning now to the table of relative humidity, we find that while stations on the coast line have at all times of the year a higher degree of humidity than those on the plains of the interior, the rate of decrease is very different in different seasons; and that in the first three months of the year the rule of increasing dryness with increase of distance from the coast line holds good only as far inland as Behar in the Gangetic plains. From Patna to Lahore the humidity of the atmosphere steadily increases to such an extent, that in March the latter station exceeds the former by 19 per cent. of saturation. I have little doubt that the Central Provinces are in like manner more humid in this season than the strip of country lying between them and the Sahyadree range, to judge from the rainfall tables; humidity observations for the latter, though existing, are unfortunately not accessible and cannot be appealed to in verification. But during a part of the time Nagpore and Jubbulpore show a higher humidity than Patna, and even than Benares.

At the hill stations the rule is also modified, and at Darjeeling from June to September the humidity of the atmosphere exceeds that of any other station either on the coast or elsewhere. I shall presently consider the effect of elevation on this element.

The coast stations show some variations which evidently have reference to the prevailing winds. Thus in the earlier months of the year (from January to May,) False Point has a higher degree of humidity than Akyab, though situated under nearly the same latitude; and during the remainder of the year this relation is reversed. A similar relation exists between False Point and Bombay, except that Bombay falls below False Point a month earlier; and a similar tendency, though less marked, is observable in the registers of Chittagong and Saugor Island. Thus then it appears that the west coasts of both peninsulas have a lower degree of humidity than the the east coast of India during the drier half of the year, while they range higher as soon as the south-west monsoon sets in.

At Saugor Island and Chittagong, January is the driest month of the year, and August the most humid; the annual range being 13 per cent. at the former station, and 18 per cent. at the latter. At Akyab the range is only 11 per cent., and March is the driest and July the most humid month. At False Point the humidity is lowest in November, that is, during the height of the rains lower down on the Madras coast; and from April to August the proportion of moisture scarcely varies, and is about 15 per cent. of saturation higher than in November.

Proceeding inland, a distance of 50 or 60 miles suffices to produce a marked decrease of humidity, especially during the prevalence of the land winds. Thus in the month of March Calcutta stands 13 per cent. of saturation below Saugor Island, and Cuttack 16 per cent. below False Point; and in the month of February Dacca ranges 13 per cent. below Chittagong. In Cachar, where the winds are chiefly from the south, and the country around is either marsh or clothed with dense forest, the humidity of the air remains high and equable throughout the year. Only in two

months, viz. in March and April, does it fall below that of Chittagong. But in Behar and in the North-Western Provinces after March the ordinary rule holds good. Thus in April Patna ranges 39 and Benares 43 per cent. of saturation below Saugor Island, while in May Jubbulpore and Nagpore are respectively 53 and 50 per cent. below False Point, and 42 and 39 per cent. below Bombay. The driest climate is that of Mooltan, where in May and June the humidity is 45 and 52 per cent. of saturation below that of Bombay.

In these instances it will have been noticed that the period of greatest siccidity falls the later in the season the greater the distance from the sea, measured along the course of the prevailing wind current. Thus while at Saugor Island and Chittagong the minimum of humidity falls in January, at Dacca in February, at Calcutta between February and March, and at Cuttack, Berhampore, Cachar, and Goalpara in this latter month, it occurs at Hazareebagh between March and April, at Patna and Benares decidedly in April, at Jubbulpore, Nagpore, and Roorkee in May, and in the Punjab between that month and June. This is clearly dependent on the advance of the sea winds, as already described in the first part of this paper.

In the North-Western Provinces and the Punjab a secondary minimum occurs at the beginning of the cold weather. This minimum falls *the earlier* the greater the distance from the sea, in the sense above defined. At Benares it falls in November, and from that month to January the air approaches more nearly to saturation as the temperature falls. At Lahore and Rawul Pindee it is in October, and at Mooltan as early as September. At this last station the normal variation of the Indian climate is reversed, and the absolute maximum of the year falls in December. At Rawul Pindee and Roorkee, both situated close to the northern hills, the winter—here the secondary maximum, falls in February, or a month later than at other stations. This winter maximum is evidently related to the winter rains of the Upper Provinces, and, like the corresponding winter maximum and rains of Europe, is traceable to the descent of the equatorial—here the anti-monsoon current, and the low winter temperature. But for this it may be inferred that the Punjab winter would be much more rigorous. The increased humidity of the winter does not affect places much below Benares. At Patna the last vestige of it is perceptible in the fact that the mean humidity of January does not fall below that of December, and at Hazareebagh the proportion remains constant from November to January. At Cuttack, however, the phenomenon re-appears, and the humidity of January appears to be higher than that either of the preceding or following months. This may possibly be due to the descent of an anti-monsoon current from the Arabian Sea, a conclusion which is favoured by several circumstances, which I shall refer to later on.

It was observed by Dr. Hooker, in the meteorological appendix of his “Himalayan Journals,” that the relative humidity of the atmosphere remains pretty constant throughout all elevations in the Himalaya, except in a Thibetan climate.\*

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\* Bessel assumed a similar law of distribution in computing his barometric formula.

The data for the hill stations in the present table generally confirm this observation, but they also show that the law is subject to considerable exceptions at certain seasons of the year. Moreover, that the local law of variation is by no means the same at all the hill stations, but varies with the character of the wind currents prevailing at each station. At Chuckrata, in the North-West Himalaya, the humidity of the air is from 10 to 12 per cent. (of saturation) lower than at Roorkee in the months of the cold weather (November to February), and from 3 to 16 per cent. higher from March to September. The general form of the curve of annual variation is the same at both stations (see Fig. 3, p. 34), but both the winter and summer maxima occur a month later at the hill station, and the spring minimum a month earlier. Next, comparing Darjeeling with Goalpara, it appears that it is only in the last three months of the year that the humidity of the hill station ranges below that of Goalpara, and then only to the extent of from 4 to 1 per cent. of saturation. In April they are equal, and in all the other months Darjeeling is the higher. This is especially the case in February, when there is a difference of 16 per cent. of saturation between the two stations. Darjeeling exhibits in a very marked degree the subordinate winter maximum already described in the Upper Provinces, but it falls later, the secondary minimum being in December, and the maximum in February. The cause is doubtless the same in both cases; Darjeeling, as we have seen, being brought by its elevation within the influence of the anti-monsoon current. At Shillong, however, no such phenomenon is to be observed, and the cause is again obvious. The north-east current from Assam, flowing down the valley and across the Khasia plateau, must drive the compensating equatorial current into a higher region of the atmosphere, and the registers of the station show that in the cold weather months the preponderating winds at this station are from the north.

The Shillong registers show further that, as compared with Goalpara, the humidity of the station is low. Except in February and December and from July to October, when it is equal to that of Goalpara (in the last month somewhat higher), the mean humidity of the hill station is from 1 to 5 per cent. less than that of the Assam valley. A similar relation is shown, but far more decidedly, by Hazareebagh, which from October to May has a drier atmosphere, not only than Calcutta and Cuttack, but even than Patna, 120 miles further inland. From October to April its humidity ranges below that of Jubbulpore, although it is less than 700 feet higher. I should not indeed venture to infer from this fact that in a vertical column of the atmosphere over the plains the relative humidity of the atmosphere would be found in the cold and early hot weather months lower than near the land surface, to any thing like the extent shown by the Hazareebagh registers. The situation of this station on the highest part of a dry plateau, freely absorbing and emitting the solar heat, while it affords little evaporation, presents conditions very different from those of the free atmosphere; and probably by raising the

temperature raises the tension of saturation, while it raises that of the vapour actually in the air only in about the same ratio as that of dry air. But I have already noticed this subject in a previous part of this paper.

In a paper published in 1870 in the 39th volume of the Journal of the Asiatic Society of Bengal, I gave tables of the average monthly rainfall at 47 stations in Bengal, Behar, Orissa, Assam, and on the Arakan Coast. In Table VI (*at end*) these have been corrected and supplemented by the registers of subsequent years and data drawn from other sources, and I have added similar tables for 41 stations in the Central Provinces, the North-Western Provinces, the Punjab, and Bombay, chiefly taken from recent registers. The whole, numbering 92 stations, give a very fair conspectus of the distribution of rainfall in Northern India, with the exception indeed of the Bombay Presidency, for which I have been able to obtain, in addition to that of the Colaba Observatory, only a few old and published tables. The rainfall map (Plate VII) has been drawn up from these data. It shows the distribution of the total annual rainfall by lines of equal precipitation, which represent increments or decrements of 10 inches. The chart cannot of course pretend to accuracy in detail, since rainfall, more than any other climatic element, is subject to local variation, being affected by local geographical conditions, such as the proximity of small hills, &c.; the lines show with tolerable faithfulness the broader features of its distribution.

I have indicated by inscriptions on the chart the tracts in which rain is received at each of the three principal seasons. Of these latter the summer and early autumn rain, that of the *rainy season* emphatically so called, is by far the most copious and extensive; so that beyond a slight recession towards the coast of the ishyetic lines of the Punjab, Upper Provinces, and Assam by the omission of the winter rains, and of those of Orissa, Bengal, and the eastern districts generally by that of the spring or hot weather rains, the map would require little modification to represent the rainfall of the first-named period only.

The cold weather rains are received most regularly and in the largest quantity in the North-Western Provinces and the Punjab, in Upper Assam and Cachar. In Behar and the Gangetic delta they are less regular and lighter. They usually begin in December and continue till March in the North-Western Provinces, till April in the Punjab. In Bengal, as we have seen, sea winds begin to be felt in February and March, and there is no period of demarcation between winter and spring rains. The same is the case in Assam and Cachar. The mean rainfall of eight stations in the Gangetic plain from Goruckpore and Benares upwards, and of eight stations in the Punjab, from November to April, is as follows:—

	Gangetic Plain.	Punjab.		Gangetic Plain.	Punjab.
November ...	0·04 inches.	0·00 inches.	February ...	1·05 inches.	1·02 inches.
December ...	0·29 „	0·53 „	March ...	0·91 „	1·29 „
January ...	1·02 „	0·53 „	April ...	0·54 „	0·81 „

These rains therefore reach their maximum a month later in the Punjab than in the North-Western Provinces. This does not coincide with the period of greatest cold, nor even with the winter maximum of humidity on the plains, but it appears to coincide rather with the latter at an elevation of 6,000 or 7,000 feet, to judge from the register of the single station Chuckrata. In any case it is determined by some cause other than mere cold, and this I take to be the humidity of the anti-monsoon current. In both cases the winter rains are followed by a break of about two months, during which a scanty and uncertain rainfall only is received from occasional thunder-storms. Stations situated near the northern hill range receive more rain than those lying towards the borders of Rajpootana, in the cold weather as at other seasons; and on the lower parts of the hills (Dehra, Kangra,) they are very copious. On the south of the Gangetic plain they are felt at Ajmere, Jhansi, and in the Central Provinces, but not further westward. Even at Mahableswhar the mean fall from December to March does not amount to half an inch, and at Bombay from December to April to less than a quarter of an inch on the mean of 23 years.

The spring or hot weather rains prevail over all that region over which sea winds set in from the Bay of Bengal at an early period of the year. In Assam and Eastern Bengal showers are pretty frequent in March or even February, and in April the rainfall is pretty general and copious. In Cachar and Sylhet in this latter month it amounts to 12 or 14 inches, and at Sebsaugor and Nazeerah, in Upper Assam, it is between 9 and 10 inches on an average. Lower down the Assam valley it is lighter, viz. 6 or 7 inches between Tezpore and Gowhatty, and at Goalpara but little more than 5 inches. Similarly on the eastern margin of the Gangetic delta it is less than in Cachar and Sylhet, viz. 8·3 inches at Comillah (Tipperah), 4 inches at Noakhally, and 5 at Chittagong. In the western part of the delta it amounts to between 2 and 3 inches (except on the coast line, where it is heavier). These rains are felt as occasional thunder-storms, known as *north-westerns*, as far inland as Nagpore, and also in Behar and in the western half of the delta much is received in this form.

The spring rains have no very definite termination, even in Western Bengal; but generally a fortnight or three weeks of hot dry weather precedes the setting in of the monsoon rains. The break of the monsoon is further marked by a change in the general direction of the wind, and seems therefore to be a phenomenon of a distinct character—something more than a mere increase in the force and regularity of the sea winds which bring the spring rains above described. In Lower Bengal, Orissa, and the Central Provinces, the change consists in a shifting of the wind to the westward; in the Gangetic plains to the setting in of ~~south~~ or south-east winds. In Assam and Cachar, however, no change of the kind takes place; from February or March the rainfall increases rapidly and steadily up to June, and then decreases gradually to the end of the south-west monsoon. But on the Arakan Coast, and on the Sikkim Himalaya, the commencement of the rains is more definite, and occurs three weeks or a month earlier than on the western part of the delta.

In Lower Bengal and Orissa the rains begin on an average in the first or second week in June, and the fall averages from 9 to 15 inches in that month: in the neighbourhood of the hills, both on the east and north, it is much heavier. They reach the North-Western Provinces later, and at Agra and Delhi the mean fall in this month does not exceed 1 or 2 inches. In Bombay they set in about the same time as in the Gangetic delta, and in the Central Provinces a week or so later; but in Rajpootana there is little rain till the following month. In the Punjab the rains are much lighter than elsewhere (except in Sind and the Bikaner desert, which latter is rainless or nearly so). They are heaviest in July; but even at Rawul Pindee, in the immediate neighbourhood of the hills, they amount to only 17·21 inches between June and September. At Lahore the total average fall is 7·71 inches, at Peshawur 4·48, and at Mooltan 3·61 only; but in the cool Himalayan valleys of the outer ranges the rains begin in June, and are far more abundant. In Hazarah from June to September the fall amounts to 22·08 inches, and in Kangra to not less than 87·08 inches according to Dr. Neil's reports.

On the Himalaya the heaviest rainfall is unquestionably on the lower and outer slopes, and it diminishes from Bhotan to the westward, but in what ratio the present data are insufficient to show. Buxa (said to be situated at 1,800 feet above the sea), on one of the outer spurs of the Bhotan Dooars, has an average annual fall (to judge from three years' registers,) second only to that of Cherra Poonji, viz. 280 inches; Rungbee, at 4,000 feet in outer Sikkim, somewhat less exposed, has 175 inches; and Dehra in the Doon or low valley between the Sivaliks and the Himalaya, 72·29 inches. The stations at elevations of 7,000 feet or 8,000 feet receive less, and show a decrease towards the north-west like those at the lower levels. Thus Darjeeling has 127 inches, Nynee Tal 86·58, and Simla 56·20 inches.

Generally the quantity of rainfall diminishes, *ceteris paribus*, with the increase of distance from the coast line, especially within the first few miles: compare, for example, Saugor Island and Calcutta, False Point and Cuttack. But it increases rapidly on approaching a hill range on the windward side, whenever the latter presents a steep face in that direction. Instances of this are afforded by Rungpore and Dinagepore as compared with Maldah; by Mymensing and Sylhet as compared with Dacca; by Goruckpore as compared with Benares; by Roorkee as compared with Agra; and by Rawul Pindee compared with Lahore. To leeward of a range, on the other hand, the decrease at the foot and gradual increase beyond is very marked: instances are afforded by Nowgong, Tezpore, and Gowhatty on the north and north-east of the Khasi Hills, and even by Shillong on their northern slope; at all of which the rainfall is much below that of Sebsaugor and Nazeerah, higher up the valley, in the direction followed by the rain-bearing south-west wind; and especially by Poonah and other stations under the lee of the Sahyadree range, as contrasted with Nagpore and others of the Central Provinces. Of the influence of

mere elevation, apart from exposure and slope of ground, no sufficient evidence is yielded by any registers available to me.

*Atmospheric pressure.*—Our knowledge of the distribution and changes of pressure is much less complete than that of temperature, or even of vapour pressure and humidity. Although barometric registers are obtainable for the whole of the area here treated of, many of them cannot be utilized in this discussion owing to the elevation of the Observatories not being known with sufficient accuracy, or to the readings being uncorrected for the error of the instrument, or even for temperature. The Punjab registers are defective in all these respects, and those of Ajmere and Dholebagan (a station in Upper Assam), which are otherwise good, cannot be used in the absence of any trustworthy determinations of level.\* The reduced readings of the Jhansi registers, here given, must be regarded as somewhat doubtful from the same cause. There remain those of stations on the Gangetic plain, in Central India, in Bengal, and on the coasts of the Bay, and for these I have data for periods of from three to five years. These are given in Tables VII and VIII, the former being the mean of the observed pressures reduced to 32° Fahr., the latter the sea-level values corresponding thereto.

For the majority of the stations the mean pressure is obtained by taking the arithmetical mean of observations recorded daily at intervals of six hours, viz. at 4 and 10 A.M. and P.M. The exceptions are Port Blair, Madras, Nagpore, Jubbulpore, and Hoshungabad, for which I have taken the means of the 10 A.M. and 4 P.M. observations, the corresponding night observations being wanting. Excepting Madras, all the means are corrected to those of the Calcutta standard barometer, which instrument reads 0.011 inch higher than the Kew standard.

In October, on the mean of the month, the pressure is nearly uniform in Bengal, and on both coasts of the Bay, in the Central Provinces, and the Gangetic valley. Such inequalities as are shown in the table and chart are small and irregularly distributed. Cuttack and False Point show the highest pressure, and Goalpara the lowest; but their difference is less than 0.1-inch, and generally over the whole area a mean pressure of 29.85 or 29.86 prevails. In the North-Western Provinces and Behar on one side, and on the Arakan Coast on the other, the pressure ranges slightly above

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\* This cannot be ascertained with sufficient approximation from the barometric readings. Barometric differences in India are in general so small, that an inconsiderable error in the assigned elevation may lead to very deceptive results when the readings are reduced to sea-level; and, on the other hand, owing to the persistence of these differences of pressure, small though they be, the sea-level equivalents of the mean annual pressure at stations one or two hundred miles apart differ sufficiently to vitiate any reasoning based on their assumed equality, and thus the fundamental assumption in the determination of heights by the barometer, viz. that when reduced to sea-level the compared pressures of the two stations are equal, is invalid. An example which strikingly illustrates this is given in the Bengal meteorological report for 1869. Cuttack and Saugor Island are about 160 miles apart, the former 80, the latter 6 feet, above mean sea-level; yet owing to a persistently low pressure during many months of 1868 in the neighbourhood of Cuttack, a comparison of the mean readings of the barometers of the two stations (recorded four times daily during the whole year), indicates a difference of 205 instead of 7½ feet.

that of Bengal, and the difference, though small, finds \* its expression in a slight converging tendency of the winds from both quarters. In like manner the small difference between Cuttack and Nagpore causes easterly winds in the direction of the latter, and that between Cuttack and the lower part of the coast a small excess of north-east winds in the north-west of the Bay.

In the following months the pressure rises over the whole area, but chiefly in the North-Western Provinces, Chota Nagpore, and Orissa. In December an axis of maximum pressure lies over Cuttack, Benares, Lucknow, and Roorkee; and Agra, Jhansi, and Jubbulpore on one side, and Calcutta, Hazareebagh, and Patna on the other, all range lower. In January and February the distribution remains much the same in its general character, except that in the latter month it falls less over the Bundelkund plateau than elsewhere, and the ridge of high pressure is pushed somewhat southward and westward. Jhansi, Benares, Jubbulpore, and Agra, now range highest in the table.

In March the pressure falls rapidly over the whole of northern India, as represented in the table, and most so in the delta, on the Hazareebagh plateau, and in Central India south of the Satpooras. These two regions are still separated by a ridge of somewhat higher pressure, which further extends across the Bay of Bengal between the low pressure area of the delta and that of Ceylon and the south of the Bay. In the existence of this ridge we have doubtless the immediate cause of the back-to-back winds described in the summary of Part I. Its existence is alluded to by Captain Maury,† though whether as an observed phenomenon or an inference from the observed course of the winds, does not clearly appear in the description. In either case, its existence is now placed beyond doubt.

In April, with a further and more rapid fall of pressure in northern and central India, the areas of minimum pressure in central India and western Bengal coalesce, and form a trough of minimum pressure, which extends from Berhampore to beyond Nagpore. To the north and north-west of this the pressure is but little higher, at least as far as Agra and Roorkee. In southern India, and over the Bay, on the Arakan Coast, and in eastern Bengal, the pressure exceeds that of any part of northern India (except possibly the Punjab). In May the trough of low pressure formed in western Bengal and Nagpore moves up somewhat to the north, and now runs east and west, from Hazareebagh along the Sone valley. The pressure of the North-Western Provinces falls below that of the delta, and a still lower pressure is established in Rajpootana.

In June the direction of the baric gradients is much the same as in May, except that, as appears from the Roorkee and Agra registers, the fall of pressure in the Punjab is much greater than elsewhere; so that the seat of minimum pressure is probably transferred to the upper part of that province. The mean difference between Port Blair at the Andamans and Roorkee in June amounts to nearly 0·3 inch, and

\* See *ante*, Part I, page 26, 27.

† *Op. cit.*, page 366.

that between Calcutta and Port Blair to more than 0·2 inch. Since Calcutta is situated about midway between Port Blair and Roorkee in the course followed by the monsoon current, it follows that the baric gradient over the Bay of Bengal is about twice as great as up the axis of the Ganges valley. The former is about one-tenth of an inch in 400 miles, the latter one-tenth in 800 miles. Such, and no greater, are the gradients that sustain the steady current of the south-west monsoon.

In July no further change of importance occurs. The pressure has reached its annual minimum. In August a general rise of ·04 or ·05 inch takes place over the whole of northern India. At Madras and in Arakan the rise is about half as much, and at Port Blair *nil*. The trough of low pressure that was formed in May south of the Ganges lasts throughout the rains, and has a marked influence on the winds. The seat of *lowest* pressure lies, however, in the direction of the Punjab and the desert of Bikaner.

Finally, in September and October the pressure increases more rapidly, and in such measure as to become nearly equalized, prior to the very different distribution which ushers in the cold season and its northerly winds.

It is evident on inspection of the charts that the distribution of pressure, to a certain extent, follows that of temperature near the ground surface, in an inverse ratio of intensity. Thus (omitting from consideration the Punjab and Upper Assam, for which barometric data are wanting,) Benares is in the cold weather the seat of highest pressure and also of lowest abnormal temperature.\* The ridge of high pressure of which this is the culminating point, and which extends in a curve from Roorkee to Cuttack,† is in like manner evidently coincident with the southward bend of the isothermals shown in the cold weather charts from November to February, especially the first of these months; and, on the other hand, the relatively low pressure of the delta coincides with the northward bend of the isothermals. In these cases, then, there is an apparent coincidence of the isobaric with the isabnormal rather than the isothermal curves. But in the hot weather months, although a similar coincidence is still traceable, the infusion of water vapour, which tends to equalize the temperature at higher levels with that near the ground,‡ is evidently influential. The trough of low pressure in April between Berhampore and Nagpore has along its axis a temperature not much below 90° when reduced to sea level, and *probably* a vapour tension higher than any part of the region to the north-west. That of Nagpore *e.g.* is 0·504 inch, and that of Jubbulpore only 0·398; that of Hazareebagh does not indeed seem so high as that of Patna and Benares, but it would appear from the table at page 39 that the vapour tension in the hot weather months diminishes very rapidly in the first few thousand feet of the atmosphere; and although I think

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\* The term *abnormal* is used in the sense given to it by M. Dove.

† See preceding page.

‡ See *ante*, page 34.

it probable that owing to the high temperature of the ground surface of the plateau, the humidity of Hazareebagh is lower than that of the free atmosphere at the same elevation, there is no reason to believe that the vapour tension is very much influenced by this cause, since there is no evaporating surface. If the vapour tension of Hazareebagh and Patna in April be compared with that of the same stations in January, the rise at Hazareebagh is seen to be proportionally greater than at Patna; and at all stations to the south and east of Hazareebagh, the relative rise very greatly exceeds that of stations to the north and west.

I infer therefore, that while the temperature of Hazareebagh near the ground level in April is but little lower than that of the delta (nearly 2,000 feet nearer the sea-level), and of Patna (which is more than 1,700 feet lower), the admixture of water vapour, though less than over the former, is probably greater than at the same elevation over the latter, and all places to the west and north-west; that a higher temperature is thus imparted to the still more elevated strata of the atmosphere, the result being to render their mean density somewhat lower than over either. The temperatures of radiation quoted at page 37 show that while more solar heat reaches the ground of the plateau in May (and it is the same in April), the nocturnal radiation is scarcely greater than on the plains of the delta, if the extreme temperatures of radiation may be accepted as a criterion of the *quantities* of heat received and emitted. And since the column of the atmosphere over the former is 2,000 feet shorter than over the latter, it may be inferred that more heat is retained in the atmosphere over the plateau, than in that above the same level over the plains. In any case, these low plateaux appear to have the effect of locally reducing the atmospheric pressure of a humid atmosphere, since the table of S. L. pressures and the charts for the months May to September show that a trough of pressure exists to the south of the Gangetic plain throughout the rains.

Throughout the rains the seat of lowest pressure appears, both from the direct evidence of the Agra and Roorkee barometers and the indirect evidence of the winds, to be in the Punjab, and this is also the seat of the highest temperature at that season. But it is also to be noticed that the commencement of the rains, (between May and July,) is marked by a fall of temperature of not less than  $15^{\circ}$  at Nagpore and nearly  $12^{\circ}$  at Jubbulpore, while the atmospheric pressure also falls by  $\cdot 087$  inch at the former and  $\cdot 128$  inch at the latter. Here the explanation is probably to be found in the diffusion of heat from the lower to the higher strata by the influx of water vapour, the tension of which increases from  $0\cdot 539$  inch to  $0\cdot 776$  inch at Nagpore, and from  $0\cdot 439$  to  $0\cdot 654$  at Jubbulpore. It has been shown in the table at page 39, that after March, the tension of water vapour at all elevated stations up to 7,000 feet rises more rapidly than near the ground surface, and also in the table at page 32 that the temperature becomes relatively higher; owing, as has also been shown with much probability, to the diffusion and condensation of water vapour. I shall presently prove, I think irrefragably, that high temperature is the most influential cause of the

fall of pressure; and if sufficient time be allowed for the communication of heat from lower to higher levels, a low pressure may be produced without any very copious accession of vapour, since the Punjab, which is the region of least rainfall and highest temperature, is that towards which the winds tend throughout the rains.

There is yet another cause which may affect the pressure to an appreciable extent, and to which I have not yet referred. It is one not usually considered by meteorologists, although Mr. Espy has resorted to it in explanation of the diurnal tides, and more recently Mr. Laughton has assigned to it more importance than I should be disposed to concede to it in atmospheric physics.\* This is the dynamic pressure of the atmosphere in motion. It follows from elementary mechanical laws, that wherever the motion of a current of air is checked or diverted, pressure must be produced; and the only question in the present connection is whether, and to what extent, it will be appreciable. A case in which, if in any, it would I think be sensible, is that in which the lower winds diverge from a circumscribed area or ridge of high pressure, the supply being necessarily drawn from above, and maintained by currents flowing in, in the upper atmosphere, from opposite quarters, and subject at the same time to cooling, by radiation, to an extent greater than is compensated by the heat set free from their arrested motion. The dynamic pressure which would arise from the contraction and sinking of the cooled air, may I think be sensible to the barometer. In no other way am I able to account for the ridge of high pressure in the cold weather months between Benares and Cuttack, where the temperature of the air, though lower than on either side, is several degrees higher than over the Gangetic plain, while the pressure is also higher. I shall presently collate the evidence, already given in these pages, of the probable existence of those upper currents which I suppose to produce this phenomenon.

I have now to consider a very important part of the subject of pressure, viz. its changes at Shillong and the Himalayan stations Darjeeling and Simla, and the evidence they afford of the height to which the density of the atmosphere is affected by the heat of the spring and summer months, and the accession of vapour. Goalpara, situated about midway between Shillong and Darjeeling, affords a convenient standard of reference for these two stations; and Roorkee, at the foot of the hills, 100 miles from Simla, may be compared with that station.

It is apparent, on a glance, that the annual range of the mean monthly pressures at all the hill stations, bears a much smaller ratio to that of stations in the plains, than do the total pressures at any season of the year: in other words, that the change of mean pressure over the plains between January and July, and *vice versa*, is chiefly due to a change in the density of the atmosphere below the elevations of these stations. The amount of this change in each month is shown in the following table. In the cases of Darjeeling and Shillong the density is

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\* Phys. Geog., page 329.

computed in two different ways—first ( $d_1$ ) from the difference of pressures at the higher and lower stations, and secondly ( $d_2$ ) from the mean pressure, temperature and vapour elasticity of the intervening atmospheric column.\* In both columns dry air at 32° Fahrenheit and 29·921 inches pressure is taken as the standard=1.

*Table showing the mean density of the air columns between three hill stations and two reference stations on the plains in each month of the year.*

### 1.—DARJEELING AND GOALPARA.

	Goalpara $b_1$	Darjeeling $b_2$	Difference $b_1 - b_2$	Mean density of air $d_1$	$\frac{b_1 + b_2}{2}$	$\frac{t_1 + t_2}{2}$	$\frac{e_1 + e_2}{2}$	Mean density of air $d_2$
January	29·003	23·344	6·259	0·837	26·473	53·6	0·325	0·844
February	·522	·322	·200	·829	·422	55·9	·336	·838
March	·442	·311	·131	·820	·376	61·7	·369	·827
April	·340	·320	·054	·809	·353	66·6	·485	·817
May	·286	·273	·013	·804	·279	69·2	·608	·809
June	·206	·228	5·978	·799	·217	71·	·713	·803
July	·135	·224	·971	·798	·209	72·4	·732	·799
August	·247	·261	·086	·800	·254	72·6	·740	·801
September	·328	·322	0·006	·803	·325	71·	·700	·807
October	·426	·391	·035	·807	·408	68·1	·582	·815
November	·567	·424	·143	·821	·495	60·6	·615	·829
December	·621	·409	·212	·830	·515	54·4	·386	·843
Year	29·402	23·320	6·082	0·813	28·380	64·6	·546	·819
Range	0·426	0·202	0·288	0·039	0·306	19·0	·424	·045

\* By the formulae

$$d_1 = \frac{(b_1 - b_2)}{12(h_2 - h_1)} 10516$$

$$d_2 = \frac{\frac{b_1 + b_2}{2} \cdot \frac{3(e_1 + e_2)}{16}}{29·921} \cdot \frac{1}{1 + .002036 \left( \frac{(t_1 + t_2)}{2} - 32 \right)}$$

where  $b_1, b_2, t_1, t_2, e_1, e_2$  are respectively the reduced barometric readings, the temperatures, and vapour tensions at the lower and higher stations, and  $h_1$  and  $h_2$  their elevations in feet.

It may be objected to the above method of computing the mean density of a column of the atmosphere from the observations of pressure, temperature, and vapour tension of two stations only, that it makes assumptions as to the distribution (more especially) of vapour and temperature, the validity of which is extremely doubtful, and which indeed can be only approximately true, when minor and temporary irregularities have been eliminated by taking for the values of  $t_1, t_2, e_1$  and  $e_2$  the averages of a very large number of observations. It may further be objected that the composition and condition of a very oblique column of the atmosphere (one of 100 miles in horizontal length), cannot legitimately be assumed to represent those of a vertical column, and that the conclusions subsequently drawn from the physical analysis of such a column, on this assumption, are therefore invalid. Some weight must doubtless be given to both these objections; but I believe nevertheless that the conclusions I have drawn are substantially trustworthy. Leaving for a moment the question of the obliquity of the column, a question which affects both computations of the density, I would point out that the errors of the values of  $d_2$ , in so far as they are due to an irregular distribution of temperature and vapour, are shown by their difference from those of  $d_1$ , since these latter are computed from independent data; and although this difference is considerable in some months, it is least so in January and July (or June at Shillong), when the exchange of air between the upper and lower strata of the atmosphere is most active, and when therefore both temperature and vapour must be least irregularly distributed. The question remains how far can  $d_1$  be accepted as representing the mean density of a vertical column. ( $d_1$ ) gives the mean density of a column of air ( $h_2 - h_1$ ) feet in length, which is equilibrated by a column of mercury at 32° Fahrenheit, represented by  $(b_1 - b_2)$ . The error, if any, must lie in the assumption here made, that  $\frac{1}{2}(b_1 + b_2)$ , the pressure at a somewhat distant hill station, really represents the pressure

## 2.—SHILLONG AND GOALPARA.

	Goalpara $b_1$	Shillong $b_2$	Difference $b_1 - b_2$	Mean den- sity of air $d_1$	$\frac{b_1 + b_2}{2}$	$\frac{t_1 + t_2}{2}$	$\frac{e_1 + e_2}{2}$	Mean den- sity of air $d_2$
January ... ..	29'608	25'262	4'341	0'863	27'432	57'8	0'352	0'863
February ... ..	'522	'238	'284	'852	'380	60'6	'354	'854
March ... ..	'442	'211	'231	'842	'326	67'2	'404	'846
April ... ..	'380	'195	'185	'832	'287	70'8	'513	'839
May ... ..	'286	'098	'188	'833	'192	73'3	'662	'830
June ... ..	'206	'060	'146	'824	'138	74'6	'747	'823
July ... ..	'195	'058	'137	'823	'126	75'2	'774	'817
August ... ..	'247	'100	'147	'825	'173	75'2	'789	'825
September ... ..	'328	'172	'156	'826	'250	73'6	'744	'831
October ... ..	'426	'247	'173	'830	'333	70'9	'642	'838
November ... ..	'567	'320	'247	'844	'443	63'5	'467	'856
December ... ..	'621	'324	'297	'854	'472	57'4	'365	'868
Year ... ..	29'402	25'190	4'211	0'837	27'296	68'3	'563	'841
Range ... ..	0'426	0'268	0'204	0'040	0'346	17'8	'437	0'51

## 3.—SIMLA AND ROORKEE.

	Roorkee $b_1$	Simla $b_2$	Difference $b_1 - b_2$	Mean den- sity of air $d_1$		Roorkee $b_1$	Simla $b_2$	Difference $b_1 - b_2$	Mean den- sity of air $d_1$
January ... ..	29'126	23'225	5'900	0'720	August ... ..	'695	'101	'594	'683
February ... ..	'048	'198	'850	'714	September ... ..	'792	'194	'598	'684
March ... ..	28'985	'197	'788	'707	October ... ..	'960	'277	'683	'694
April ... ..	'878	'207	'671	'692	November ... ..	29'104	'293	'811	'709
May ... ..	'747	'142	'605	'686	December ... ..	'154	'254	'900	'720
June ... ..	'682	'061	'571	'680	Year ... ..	28'895	23'185	5'712	0'698
July ... ..	'638	'069	'569	'680	Range ... ..	0'522	0'232	0'331	0'040

at height ( $h_2 - h_1$ ) vertically over the station when the pressure is  $b_1$ , and such error would arise were there a persistent difference of pressures between the two places in the same horizontal plane. Now, any such difference would tend to produce wind-currents from one place towards the other, and this tendency should be shown by the wind registers. *There are* such currents in July, from Goalpara towards Darjeeling, and from Roorkee towards Simla, indicating therefore the existence of a somewhat greater pressure over the former stations than at the latter in the same horizontal plane. But from the annual range of pressure at the hill and plains' stations given in the table above, it appears that this difference of pressure at the height of 7,000 and 8,000 feet is probably not more than half as great as at the ground surface, where the barometric gradient does not exceed 0.1 inch in 800 miles, or 0.012 in 100 miles (see text page 48.) Take the probable error of  $b_2$  then as .006. Then increasing the value of  $b_2$  by that amount, the value of  $d_1$  will be diminished by 0.001, and that of  $d_2$  increased by half as much. The error of the results in the month of July cannot therefore much exceed this. In January the mean movement of the air is so low that the errors of the assumption similarly estimated must be quite insignificant.

I should expect that the differences of  $d_2$  and  $d_1$  are principally due to the real mean temperature of the air column in most months being somewhat higher than the assumed temperature  $\frac{t_1 + t_2}{2}$ . A certain amount of error must arise also from

the fact that the adopted values of vapour tension are probably in all cases lower than the real tensions, but the effect of this cannot be very great.

From these tables we learn a fact of high importance, viz. that of the whole annual oscillation of the atmospheric pressure over the Gangetic plain, which may be taken as the measure of the forces that produce the alternating monsoons of India, (up to the equator, where the pressure is nearly invariable), nearly one-half is due to an alteration of the density of that stratum of the atmosphere which lies between 400 and 5,000 feet (Goalpara and Shillong), more than two-thirds to that of the stratum between 400 and 7,000 feet (Goalpara and Darjeeling), and nearly two-thirds to that between 800 and 8,000 feet in the North-Western Provinces (Roorkee and Simla). If for the actual annual barometric range at Goalpara and Roorkee we substitute their equivalents at sea level, as given in Table VIII, viz 0.445 inches at Goalpara and 0.595 at Roorkee, and increase the range of the values of  $b_1 - b_2$  by a corresponding amount, then the oscillation below Shillong becomes more than one-half, and that below Darjeeling and Simla nearly seven-tenths of the whole.

Further, it is to be noticed that the change of density in the North-Western Provinces considerably exceeds that in Bengal, and affects the atmosphere to a greater height, since the annual oscillation of pressure is absolutely greater at Simla at an elevation of 8,055 feet, than at Darjeeling at 6,941 feet. Even as measured from the plains below, Simla is nearly 1,000 feet higher than Darjeeling. Calling the annual mean density of the atmospheric column below the hill station in each case = 1, the range between January and July is 0.048 in Bengal, and 0.057 in the N. W. Provinces.

If the method of computation which gives the values  $d_2$  be accepted as legitimate, by varying successively each of the terms  $(b_1 + b_2)$ ,  $(t_1 + t_2)$ , and  $(e_1 + e_2)$  in the formula for  $d_2$ , while the others remain constant, we may ascertain another fact of high importance, viz. the degree in which the density of this column is affected respectively by the variation of the top pressure, the rise of temperature, and the introduction of additional vapour in the place of dry air of the same pressure. Between January and July the mean density of the air below Darjeeling falls from 0.837 to 0.798. This total difference is made up in the manner following.\*

(1). By decrease of the top pressure from 23.344 inches to 23.224, the mean density of 0.837 would be reduced to 0.832.

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\* These values are obtained by the following formulæ, by which, from the figures in the table on pages 51, 52, the change of density arising from the variation of any element between two given months may be found. Calling  $B_1$  and  $B_2$  the initial pressures at the lower and higher stations,  $b_2$  the final pressure at the latter;  $T$  and  $t$ ,  $E$  and  $e$ , the initial and final mean temperatures and vapour tensions respectively, and  $D$ ,  $d_b$ ,  $d_t$ , and  $d_s$ , the initial observed and final computed densities respectively, we have—

$$d_b = D \cdot \frac{b_2 \left(1 + \frac{B_1}{B_2}\right)}{B_1 + B_2}$$

$$d_t = D \cdot \frac{1 + .002036 (T - 32)}{1 + .002036 (t - 32)}$$

$$d_s = D \cdot \frac{(B_1 + B_2) - \frac{1}{2}e \cdot \frac{1 + .002036 (T - 32)}{1 + .002036 (t - 32)}}{(B_1 + B_2) - \frac{1}{2}E}$$

(2). By increase of the mean temperature from  $53.6^{\circ}$  to  $72.4^{\circ}$ , the mean density of 0.837 would be reduced to 0.807.

(3). By the infusion of water vapour, which, in conjunction with the rise of temperature, raises the mean vapour tension from 0.325 inches to 0.732 inches, the mean density of 0.837 would be reduced to 0.832, supposing the temperature to remain constant.

And summing up these differences, we find—

Density of air in January	...	...	...	0.837
				<hr/>
Reduction due to decreased pressure above	...	...	...	0.005
Ditto ditto increased temperature of column	...	...	...	0.030
Ditto ditto introduction of water vapour	...	...	...	0.005
				<hr/>
Total reduction	...	...	...	0.040
				<hr/>
Density of air in July...	...	...	...	0.797
				<hr/>

which accords almost exactly with that obtained from the difference of observed pressures, viz. 0.798.

Thus then it would appear that the increased temperature of the column itself reduces its density to an extent six times as great as is effected either by the decrease of pressure above, or by the large increase of its vapour constituent, and if we may further assume that the second of these elements results from the variation of the other two in the like proportion, and that the condition of the oblique column of air between Darjeeling and Goalpara fairly represents, for our present purpose, the general state of the atmosphere over Lower Bengal, we must conclude that *of the reduction of the atmospheric pressure between January and July on the plains of Lower Bengal, six-sevenths are due to the increased temperature of the atmosphere, and only one-seventh to the displacement of dry air by aqueous vapour.*

I have not at present the data for a similar analysis of the density of the atmospheric column between Simla and Roorkee, or indeed any pair of stations in the drier climate of the North-Western Provinces, but it can hardly be doubted that such an analysis would show results more or less similar to the above; and it may be expected that the lower mean pressure of the atmosphere from May to September would be found to depend on its higher mean temperature, up to a height of about 9,000 or 10,000 feet. That the mean temperature of the column below 7,000 feet is actually higher in the neighbourhood of the hills of the North-Western Provinces than that of the similar column below the Sikkim Himalaya, is shown by the following comparison of mean temperatures of the atmosphere below Chuckrata and Darjeeling, situated at nearly equal elevations above sea-level.

*Table of the mean temperature of the air columns below Darjeeling 6,941 feet, and Chuckrata 6,884 feet.*

	Darjeeling.	Chuckrata.		Darjeeling.	Chuckrata.
January ... ..	53·6	50·1	July ... ..	72·4	75·1
February ... ..	55·9	53·4	August ... ..	72·6	74·6
March ... ..	61·7	59·9	September ... ..	71·	72·6
April ... ..	66·6	69·9	October ... ..	68·1	67·6
May ... ..	69·2	78·6	November ... ..	60·6	58·6
June ... ..	71·	79·2	December ... ..	54·4	50·8
Year ... ..	64·6	65·9	Range ... ..	19·	29·1

Changes of temperature are then the principal cause of the variations in the weight of the atmosphere, but the part played by vapour is not the less important, though its action is chiefly indirect. This action is evidently to equalize the temperature of the air column, to carry heat from the lower and more highly heated strata to those at greater elevations, and also, as Dr. Tyndall has shown, to arrest and absorb both solar and terrestrial radiated heat in its passage through the atmosphere. Indirectly therefore water vapour greatly influences the pressure, though the change of density that arises from its displacement of the heavier constituents of the atmosphere is relatively small, and in some cases unimportant.\*

With respect to the interior of India, the course of events appears to be as follows:—From March onwards, the air immediately over the elevated plains is gradually raised to a high temperature, but at first only in the lowest stratum. By

\* The facts thus indicated relative to the effects of temperature and vapour in affecting pressure, seem to explain the apparent anomalies that have led some authors, especially Mr. Laughton, (Phys. Geog., pp. 120, 123,) to question the soundness of Hadley's theory of the trade winds. These are, that winds do not blow centripetally towards the Sahara, the Arabian Desert, the interior of Australia, &c., all of them dry regions with a day temperature very much above that of the neighbouring seas. In the first place Mr. Laughton has I think, insufficiently considered the fact that a high day temperature in these dry regions generally alternates with a low night temperature; the nocturnal radiation being intensified by the same conditions which increase the incident solar heat; so that the mean temperature of the 24 hours, one element of importance in determining the general system of the winds in such regions, is frequently below that of places with a much lower day temperature. *Ex. gr.*, Lahore in April has a mean maximum diurnal temperature of 98·4°, Calcutta one of 93·5°, but the mean temperature of the 24 hours is only 79·1 at Lahore, while at Calcutta it is 84·5°. Further, the facts discussed in the text and tabulated at pages 32 and 51, 52, show that in a dry atmosphere the high temperature prevails only in its lowest stratum, and that the mean temperature of a column of comparatively dry air, say 7,000 feet in height, may have an average temperature 16° below that of the surface, while another equal column of moist air averages only 9° or 10° less than near the ground. Surface temperature alone especially that of the day time, is a very unsafe criterion of the average temperature of the atmosphere above the place of observation. But in the equatorial calm belt, to which region Mr. Laughton applies conclusions drawn from Arabia, Australia, &c., the atmosphere is highly charged with vapour, and the decrease of temperature with elevation therefore probably slow.

degrees, convection currents from the sea, of no great vertical thickness, are drawn in to this lower stratum, introducing vapour, which carries the heat by diffusion and condensation to a greater and greater height. Up to the end of May or the beginning of June, this diffusion of heat, while reducing the pressure, does not lower the temperature of the surface; and it is only when, in June, a strong steady current of nearly saturated air is drawn from the equatorial seas, that the precipitated vapour, partly as cloud and partly as rain re-evaporating, absorbs the excess of solar heat and reduces the temperature of the lower atmosphere to the extent shown in the temperature table.

There is yet another point of importance to be noticed in the tables on pages 51, 52. While the stations at the lower levels, Goalpara and Roorkee, as well as all others on the plains, show but one annual maximum and one minimum of pressure, the former in December, the latter in June or July, the two hill stations (Darjeeling and Simla) have two maxima and two minima like places on the Atlantic coast of Europe. The epochs of the maxima and minima are however very different in the two cases. The absolute minimum of the year at these hill stations coincides with that on the plains, and is doubtless due to the same cause; but the absolute maximum falls in November at the former, and is followed by a fall, at first rapid, and gradually decreasing till March. A small rise then takes place, which brings the mean pressure of April above that of February; it is, however, only temporary, and in May and June the pressure falls rapidly to its minimum.

The fall of pressure in December and January is, I think, evidently due to the rapid condensation of the lower stratum of the atmosphere by the radiation of its heat, and, while this cooled air flows away to the south as the source of the north-east monsoon, by the consequent setting in of a compensating anti-monsoon current of higher humidity and comparatively equable temperature, at (or in the case of Darjeeling chiefly *above*) the level of the hill stations. From January to March as well as from April to October, the pressure at Darjeeling and Simla must, on this assumption, be lower than at equal elevations to the southward in the course of this upper current.

The temporary rise in April is, I think, to be attributed to the expansion of the lower atmosphere, by which, for a time, a larger proportion of the atmosphere is lifted above the level of 7,000 and 8,000 feet. This requires further investigation.

*Certain effects of the winds.*—I have now discussed most of the more important facts relating to temperature, vapour diffusion, and atmospheric pressure, to be gathered from the registers of the past few years, in so far as they bear on the causes of the winds. It remains to notice certain effects of the winds, especially on temperature and rainfall, and I shall then briefly sum up the results of the whole discussion, and add a few remarks, in an Appendix, on the storms of the

Bay of Bengal; to the explanation of which a knowledge of the normal wind system is indispensable.

In respect of temperature, it is obvious that, except in the case of dynamic heating and cooling, a wind cannot *per se* raise the temperature of a place above, nor depress it below, that of the region from which it immediately comes. Any change of temperature that it may undergo along its course must, therefore, be due to local causes, such as evaporation, radiation, or the absorption of solar or terrestrial heat *in transitu*. The effect of a wind is to tend to equalise the temperature of places along its path. Before applying this postulate to the meteorology of the region in question, it is then necessary to consider those changes of temperature that may arise from dynamic causes; and of these one class of cases only need be noticed, viz. that of a current which is cooled by a rapid ascent to a higher level, or heated by descent to a lower level. The latter if recognizable will chiefly affect the temperature of stations on the plains, the former that of hill stations.

Both these actions doubtless take place on a great scale over the plains of Northern India; since we have seen that at one season this region is the *terminus a quo*, at another the *terminus ad quem* air currents are set in motion; and during the continuance of these currents there must be a constant passage of air from the higher to the lower strata, or *vice versâ*. If, then, dynamic heating be appreciable, it should be detected in a relatively higher temperature of the air on the plains of Upper India in the cold weather months; and for evidence of cooling by the ascent of the air, we should look for a relatively lower temperature of the hill stations in the months of the rains—the effect in either case being shown by a difference of temperature between hill and plains stations greater than at those times when the interchange between the different strata is at a minimum. But the evidence tabulated at page 32 shows that it is precisely at these former seasons that the temperature difference is *least*, and that it is *greatest* at the change of the monsoons. We have also seen that where the anti-monsoon current descends in greatest volume, viz. the plains of Upper India, is the coldest part of India at that time of year, and the temperature difference between Chuckrata and Roorkee is then not only at its annual minimum, but it is also less than between Darjeeling and Goalpara, where the descent of the anti-monsoon is but little felt. The conclusion is obvious. Any change of temperature that may arise from dynamic causes is completely neutralized by other causes operating in a reverse direction, and the residual excess of the opposite effects are at their maximum when these dynamic causes are most active. This is in entire accordance with the conclusions of *à priori* reasoning, and consistent also with the view that differences of temperature are the principal cause of wind.

Dr. Mühry, in a recent work on the winds (Untersuchungen über die Theorie und allgemeine Geographische System der Winde, page 99), attributes the heat and dryness of the westerly winds of the Gangetic plains between March and June in a great measure to dynamic heating; but his view of the origin of these winds is

certainly erroneous. He adduces them as an example, on a great scale, of an air-cascade flowing from Tibet over the ridge of the Himalaya, and a retroversion of the current in the hollow of the fall (Windschatten). I transcribe the passage in a footnote.\* Of the existence of a north-east current across the crest of the Himalaya, I can find no evidence in the account of any traveller in high Himalayan regions. From the accounts of Dr. Hooker, General Strachey, M. Schlagintweit, Mr. Shaw and others, it appears that amid all the local irregularities due to the varying direction of the valleys, the prevalent winds are southerly up to the principal range, and that day winds of great force, attributed by General Strachey to the heating of the elevated plains, blow in the same direction through the passes. Only in Turkistan does the prevalent wind appear to be northerly up to the Mustagh or Karakorum range. The hot westerly winds of the Gangetic plain and an extensive region to the south, in April and May, are, as Dr Hooker long ago pointed out, essentially day winds, and due to the heating of the soil.† Were they what Dr. Mühry supposes, they would probably be felt by night as well as by day, but we have seen that in the hot weather in Upper India the nights are generally calm, and the temperature falls lower than in Bengal.

The effect of the winds in tending to equalise the temperature along their path is very distinctly exhibited in the charts for the cold weather months, more especially that of November. The cool current from the North-Western Provinces flows most steadily down the Gangetic valley, across Western Bengal and the tract intervening between this province and Nagpore; and it is here that the isothermals make their great southerly bend. Their northerly curvature opposite to the Gulf of Cambay and in Eastern Bengal shown more or less distinctly in all the cold weather months, I can attribute only to the influence of the anti-monsoon currents flowing at lower levels in those regions. The evidence on this head afforded by the tabulated observations of the surface winds is, of course, not very distinct, but is not altogether wanting, and as far as it goes, lends support to this view. I have noticed in Part I (pages 23 and 27) of this paper that southerly winds blow on the Arakan Coast a

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\* "In Asien gibt zunächst der Himalaya, Gelegenheit zu Entstehung eines grossen Beispiels unserer Erscheinung auf dem Continente; so scheint wenigstens ein gewisser endemischer Wind in Nördlichen Ostindien seine Erklärung zu finden. Längs der südlichen Seite dieses mächtigsten Gebirges, welches ja ebenfalls nach nordwest hin streicht, etwa von 27° bis 35° N, ist wohl bekannt, dass in der heissesten Zeit, im trockenen Frühjahr, von März bis Mai, zur Zeit, wenn in übrigen Ostindien, und man kann sagen in übrigen Sud-Asien, der nordost-monsun herrscht, das ist der Polarstrom, noch ungestört in seiner untersten Schicht durch den Sommerlichen Seewind, den S. W. monsun, dass dann das ganze Gangesthal hinunter ein N. W. anhaltend weht, warm und von excessiver Trockenheit. Es darf uns kaum Zweifelhaft erscheinen, dass dieser Wind gleichfalls einen Windfall und retroversion des N. O. Passats darstellt." It is doubtless owing to the dearth of information hitherto accessible on the subject of the normal winds of India, that Dr. Mühry has been misled into the belief that N.E. winds are generally prevalent in India between March and May. The idea that a polar-stream flows from Central Asia across the Himalaya is an error of old standing.

† These winds form a very interesting subject for investigation, but I cannot attempt it at present. They must be considered in connection with the diurnal variation of temperature and pressure. In connection with the latter, I may mention that they generally set in at the time of the morning maximum, and I expect their explanation is to be found in a study of the barometric tides.

full month after they have ceased on the opposite coast of India, and at Dacca calms are very common in the cold weather months, which is not the case normally at Calcutta.\* Moreover, the diurnal movement of the wind in the four months of the cold weather averages 46·6 miles only at Dacca, while at Calcutta it is 98·1 miles per day. At Ajmere, again, southerly winds are in excess both in October and February, and they are very common both in December and January; and here too, as in the North-Western Provinces, (but not in the Central Provinces,) calms are very common throughout the cold weather.

The isobars afford evidence to a similar effect. In all the cold weather months there is a lower mean pressure over Eastern Bengal, and, as far as evidence goes, apparently opposite the Gulf of Cambay (certainly on the Bombay Coast), than in the region between Nagpore and the Gangetic delta. I conclude then that while the anti-monsoon currents exist probably over the whole of Northern India, they flow in greater volume and at lower levels in Eastern Bengal and opposite the Gulf of Cambay than elsewhere.

In the hot weather the course of the isothermals is evidently determined chiefly by the form of the land; but in July the cooling influence of the monsoon currents, setting in from both coasts, is very distinctly shown in the chart; and up to September the hottest region is that most remote from the coast, as measured along the course of the rain-bearing winds.

With respect to the influence of the winds on rainfall, little is to be added to what has already been said. The winter rains are, I conclude, dependent upon the descent of the anti-monsoon current, and to the cooling which it undergoes by radiation either of the air directly, or of the land surface with which it comes in contact. In December and January the isotherm of  $63^{\circ}$  or  $64^{\circ}$  coincides approximately with the limit of the region in which the rains are pretty regular, but they are felt occasionally up to the isotherm of  $70^{\circ}$ , and even beyond.

When the sea winds set in on the coasts of Bengal and Orissa in the early spring months—winds which I have said are at first restricted to the lowest stratum of the atmosphere—they bring the vapour, which is precipitated as the spring rains, chiefly in the form of storms. It is at the beginning of this season that hail-storms are most frequent. In Lower Bengal two or three such storms generally occur in the month of March, and may be traced to the meeting of the land and sea winds, and probably to the dynamic cooling of ascending currents.† The heavier rains of Eastern Bengal are determined probably by the character of the country—hills for the most part covered with forest, and with marshes extending up to their foot. The evaporation

\* At both of these stations calms have been recorded regularly throughout the period represented in the tables.

† The storms of this time of year are well known as nor'-westers. They are generally accompanied by violent electrical discharges, and the barometric column invariably rises rapidly on their approach, sometimes to the extent of 0·1 inch; so that on looking back through a series of diurnal barometric curves, it is easy to detect those days on which storms have occurred. They occur most frequently about 5 or 6 in the afternoon.

is such as to keep the ground and superincumbent air lower in temperature and more humid than anywhere in Western Bengal.

In the rains as well as in the hot weather, the winds are checked on reaching the coast line, as is evident from the great difference in the mean diurnal movement of the air at Saugor Island and Calcutta; and there must accordingly be an ascending stream or eddy, which causes a large precipitation of the vapour within the first few miles bordering the coast. Of this the rainfall table and chart bear evidence.

The strip of elevated country south of the Ganges, in which (it would appear from the few registers that have been kept in this tract) the rainfall averages more than 50 inches, coincides with the trough of low pressure described at page 47 and indicated on the charts for the summer months, especially May and August. It coincides also approximately with the line separating the westerly monsoon current of Central India from the easterly monsoon of the Ganges valley.

The Central Provinces to the south of the Satpooras, and even for some distance to the north of that chain, receive their rains wholly from the west coast. Much of this country is very hilly, but it is not all of this character: and the numerous feeders of the Godavery drain a system of plains, which have mean elevation of less than 1,000 feet above the sea, and fall away to the south-east. Yet the rainfall is here heavier than on the Deccan plateau nearer the Ghâts, which must of course be crossed by the rain-bearing winds, excepting such portions as may pass up the valleys of the Taptee and Nerbudda. This appears anomalous, but I think the explanation may be found partly in the facts to which General Strachey drew attention in the paper I have before referred to (page 39). He there showed that the distribution of vapour vertically in the atmosphere on the hypothesis of independent atmospheres of dry air and water vapour, is inconsistent with the known ratio of temperature decrement with elevation, inasmuch as such a distribution would require the existence at comparatively moderate heights of a vapour tension above that of saturation. But vapour must always *tend* to assume such a distribution, and thus a current, which has already been robbed of a large part of its vapour by passing over the Sahyadree ridge, even though rendered hygrometrically dry on re-descending to lower levels, may gradually become resaturated in its higher strata by the upward diffusion of its residual moisture. After the first falls, moreover, if the current is uninterrupted, a portion of the precipitated rain, which may be roughly estimated between one-fourth and one-third, will be again taken up by evaporation and carried further inland, again to be precipitated. In this way probably also is to be explained the gradual advance of the rains up the Ganges valley to the Punjab, a progress which occupies three or four weeks from the setting in of the heavy rainfall in Bengal.

The rainless, or nearly rainless, climate of Sind and the plains of Bikaner owes its character doubtless to that of the arid countries to the west and north-west. In the absence of any wind observations in this region, this cannot be verified, but

a very probable explanation is furnished by the following considerations. This region, including the Punjab, appears to be the seat of the lowest pressure in the rainy months, and it has been shown from the wind registers of the last named province,\* that during this period of the year there is a kind of cyclonic circulation of the winds around it. Accordingly, and this the wind and rain registers show, on its northern and eastern borders it receives a moderate rainfall from winds that reach it from the east and south-east, having travelled up the Ganges valley or across the Satpoooras and the Malwa and Bundelkund plateau; but on the south and west, if the rule there holds good, they must come from Beloochistan, Arabia, and Persia, all exceedingly dry countries. As far as I can speak from my recollection of a register kept at Khelat some years since, such rain as falls on the hills to the west of the Indus comes from the eastward.

#### GENERAL SUMMARY.

The north-east monsoon of Indian seas is produced by the cooling and condensation of a comparatively calm atmosphere over the land surface of India. It has its origin in the plains of the Punjab, Upper and Central India, and Assam; probably also on the southern slopes of the Himalaya, where the air, cooled by radiation and contact with the surface of the hills, flows down the large valleys to mingle with the similarly cooled air of the plains. These currents are fed by an upper current, which I have termed the *anti-monsoon*. This is felt as a southerly wind on and over the south face of the Himalaya, and descends on the plains of Upper and Central India, bringing the winter rains. There would appear to be two principal branches of this current, the course in each case being indicated by a higher temperature and lower pressure ~~of~~ the surface of the ground, as well as by the longer duration of southerly winds. One of these flows at a lower level opposite to the Gulf of Cambay, over a part of Rajpootana, and a portion at a higher level flows eastward above the Ghâts, and descends on the hilly country east and north of Nagpore. The other branch, coming from the Bay of Bengal, holds its course at a lower level over Eastern Bengal, and then the major portion, curving to the west and north-west, blows on the south face of the Himalaya; and flowing off sideways, probably meets the Arabian Sea current along a line indicated by a ridge of high mean pressure at the ground surface. This line passes through Roorkee, Lucknow, Benares, and Cuttack, and coincides with the axis of the stream of cold air from Upper India. The east or north-east monsoon of the Wynegunga plain and the north-west monsoon of Lower Bengal radiate out from this ridge of pressure and flow away as very gentle currents, in the one case towards the Arabian Sea, in the other to the Bay of Bengal. A portion of the Bengal anti-monsoon current probably flows north-eastwards to Assam, where it brings rain, and feeds

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\* *Ante*, Part I, pages 7 seq.

the Assam and East Himalayan branch of the north-east monsoon; but further evidence is required to establish the existence of this current.

This double system of upper and lower currents will be rendered more comprehensible by the annexed woodcut (Fig. 4), on which the upper currents are shown by dotted, the lower by continuous lines.



Fig. 4.—Lower and Upper winds N.E. monsoon.

The evidence on which the above description is based may be briefly summed up as follows:—Firstly, the course of the winds in the lower atmosphere as shown by the wind registers. The cold dry north-west current, which begins in Upper India, increases in steadiness and strength, probably therefore in volume, as it moves towards Western Bengal. It increases also as the season advances. This is shown by the following velocities registered at stations on or near the central course of the current, and extracted from the wind tables given at the end of this paper: Calcutta, it should be remarked, lies at a lower level than Hazareebagh, and it is probable that after passing the plateau of Western Bengal, the current does not descend completely to the low level of the delta, but more frequently holds on its course at the elevation it has already attained.

Table showing the increasing mean movement of the North-West Current during the Cold Weather.

	November.	December.	January.	February.	
Roorkee ... ..	19·2	25·4	40·2	47·	Miles per day.
Benares ... ..	55·	34·2	55·6	73·3	ditto.
Patna ... ..	51·7	34·4	64·6	72·8	ditto.
Hazareebagh ... ..	91·1	92·7	98·	131·4	ditto.
Calcutta ... ..	82·1	91·2	104·5	114·8	ditto.

Secondly, on the Himalaya, especially the north-west portion, southerly winds prevail throughout the cold weather, and at stations 7,000 or 8,000 feet above the sea the atmospheric pressure falls in December and January, while on the plains it rises in December, and does not begin to fall till the end of the latter month. Thirdly, in Upper India and the Punjab, easterly winds, bringing rain, are much more common than in Bengal, and the atmosphere is characteristically calm. Winter rains also occur in Central India, where the lower current is from east and north-east. Fourthly, there is a ridge of high mean pressure running from Roorkee through Benares to Cuttack, which I can account for only on the supposition that it coincides with a trough of low pressure in the upper atmosphere where the currents from north-east and south-west meet and descend. Fifthly, there is in Eastern Bengal a region of low pressure where the northerly wind is unsteady and much interrupted by calms. It is in the prolongation of the line of the Arakan Coast where the southerly monsoon blows a month longer than on the Indian coast. This, I suppose to indicate the course of a main stream of the anti-monsoon which is here lower than over Western Bengal, but does not, at least in general, descend to the land level.\* Sixthly, the isothermal lines bend northward, (indicating a relatively high temperature,) opposite the Gulf of Cambay and in Eastern Bengal, and south-wards between Western Bengal and Central India. The former, I suppose to indicate the course of the two principal branches of the anti-monsoon flowing northwards, the latter the place of their meeting, descent, and return as the beginning of the northerly monsoon.

The south-west monsoon is produced by the heating of the land surface of the peninsular and the superincumbent air, to a temperature much above that of the sea to the southward. Six weeks before the vernal equinox sea winds begin to set in in the lowest stratum of the atmosphere, on the maritime belt of Lower Bengal and Orissa, and gradually advance further and further inland. At the same time over the whole of Northern India the winds continue to blow from the westward, rising gradually in temperature, and at length blowing only or chiefly in the day time as the hot winds of April and May. This state of things depends probably on the high temperature being restricted to the stratum of air immediately over the ground. But with the advance of the sea winds and the upward diffusion and condensation of their vapour, the heat also is diffused to higher levels. In May the rise of temperature at 7,000 and 8,000 feet proceeds as rapidly as on the plains, or even somewhat more so. By this diffusion of heat and the increasing temperature of the ground surface and the lower strata of the air, under a nearly vertical sun, the pressure falls steadily, and the sea winds are drawn from a greater distance south. At length, as seems probable, in June, the ridge of high pressure over the sea, which has steadily receded southwards since February, is obliterated, and the south-east trade, or perhaps only a portion of it, crossing the line, brings the monsoon rains to Bengal and the

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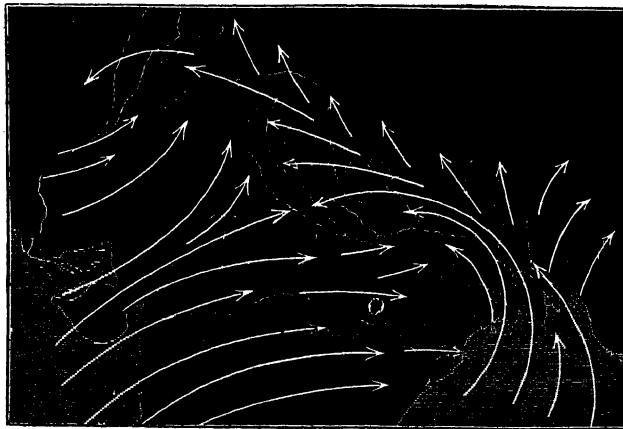
\* When rain does occur, or the sky is cloudy, at Calcutta in the cold weather, there is generally an easterly, south easterly, or southerly current above and calm below.

west coast of India.\* The two principal divisions of the monsoon, advancing from opposite sides of the peninsula, appear to follow a course very similar to that of the anti-monsoon currents of the winter season, but of course more influenced by the irregularities of the land surface. The Arabian Sea branch blows right across India, and is felt as a westerly wind in Orissa, and even beyond to the eastward, being probably influenced by the direction of the Satpooras and their virtual continuation in the plateaux of Sirgoojah, Chota Nagpore, and Hazareebagh; while the Bengal current is restricted to Assam and Cachar, Bengal and the Gangetic plain. The moist south winds blow up to the Himalayan snows, and even beyond into Tibet, but this is probably their limit in that direction; and westward up to the further limits of the Punjab plains. The greater part must form an ascending current over the plains, and return southwards at such a height that it is doubtful if any direct evidence of it is forthcoming. I am unable to agree with Dr. Mühry's conclusions on this head; but of these I will speak presently. That the mean movement of the air decreases from the coast line inland is shown by the following table:—

*Table showing the decreasing velocity of the south-east current up the Gangetic Valley during the south-west monsoon.*

	June.	July.	August.	September.	
Saugor Island ... ..	201	255	262	242	Miles per day.
Calcutta ... ..	198	157	139	132	ditto.
Hazareebagh ... ..	185	152	132	129	ditto.
Patna ... ..	90	81	81	84	ditto.
Benares ... ..	95	73	70	58	ditto.
Roorkee ... ..	73	53	38	27	ditto.

The accompanying chart shows the average course of the wind currents during the height of the south-west monsoon. To what height they extend, there is no evidence to show, but it is probably much greater than that of the north-east monsoon currents in Northern India.



*Fig 5.—Lower winds S.W. monsoon.*

\* See *ante*, Part I, page 25. Also Maury's Physical Geography, Edit. 12th, page 367; and Meldrum, British Association Report, 1867, Part II, page 21.

This conclusion is, I think, in accordance with the evidence adduced in the foregoing pages, which at least establishes the superior steadiness, velocity, and extension of the south-west monsoon current. It is, however, at variance with that of Dr. Mühry, and it is but due to the recognized eminence of that writer, that I should specify why and wherein I differ from him. Dr. Mühry considers that the south-west monsoon is a phenomenon of less magnitude than the north-east monsoon, which he regards as identical in character with the north-east trade of the North Atlantic and of equally remote origin. The passage has been quoted in a preceding page, in which he speaks of it as a current proceeding from Central Asia. He regards both the north-west monsoon of Australia and the south-west monsoon of India as a deflection or retroversion of the lowest stratum of a perennial trade-wind; and infers from the perennial northerly flow of the smoke of the Merapi volcano in Java, and the prevalence of winds from between north and west at Dodabetta during the south-west monsoon, quoted by Colonel Sykes, that the former current is not more than 6,000 feet, the latter 9,000 or 10,000 feet in vertical thickness. In regard to the latter, I will observe in the first place that it has already been shown that the north-east monsoon of Indian Seas has its origin in Northern India, and is there, at all events, a current of less depth and magnitude than Dr. Mühry supposes: since the winds on the North-West Himalaya at 7,000 or 8,000 feet are throughout southerly. There is, then, no reason to infer that the south-west monsoon is merely a deflected current of a trade-wind, the very existence of which over India is negatived by the evidence. Secondly, Dr. Mühry has omitted to notice certain observations of Colonel Sykes, which at least imply doubt of the north-west winds of Dodabetta, being the return current of the south-west monsoon. He says that "it very frequently blows from only one or two points to the northward of west, and may belong to the monsoon of Western India, local physical circumstances having given it a slant."\* There is nothing improbable in this explanation, as the broad valley in which lies the station of Ootacamund runs up to the north-west of the peak, and in mountain tracts, the winds on peaks and ridges are always much influenced by the direction of the valleys. I am not prepared to deny the possibility of a return current being occasionally felt at 8,600 feet (the height of Dodabetta), but the evidence is at least inconclusive, and the superior velocity and steadiness of the south-west monsoon render it probable that it is a current of greater depth and volume than the north-east monsoon. As to the north-west monsoon of Australia, and the evidence of the Merapi volcano, I do not think the case has much bearing on the question of the monsoons of India. It is clear that the monsoon is not a single great current, proceeding to or from Central Asia, but consists of several currents, to some extent independent of each other, flowing to or from more than one centre on the Asiatic continent; and there may be a deep

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\* Phil. Trans., 1850, Vol. CXI, page 373.

north-easterly current flowing from India to the south and south-west of that region, and a very shallow one opposite the Malay Peninsular. I certainly could not accept without much stronger evidence than has yet been adduced, the complicated system of winds during the south-west monsoon, supposed by Dr. Mühry, viz. a south-west current up to about 9,000 or 10,000 feet, which is a retroversion of the lowest stratum of the trade-wind; above this "the remainder of the trade-wind, moving undisturbed from the north-east; and over this the returning anti-trade moving from south-west at a still greater elevation." With much of what Dr. Mühry has written on the subject, I should however add that I cordially agree.

The annual range of atmospheric pressure, which at Roorkee, when reduced to sea-level, amounts to 0.6 inch on the means of the months, is due principally to a change of density in the lower 7,000 or 8,000 feet. The proportion below Simla and Darjeeling is nearly seven-tenths of the whole. Six-sevenths of this in the case of the latter are probably due to the expansion of the atmosphere by increase of temperature, and only one-seventh to the substitution of water vapour for dry air. But water vapour, though of subordinate importance in this respect, plays an important part in communicating heat to the higher strata of the atmosphere, carrying it upwards by its diffusion, in the form of latent heat, which is emitted by its condensation; and also by arresting and absorbing the solar and terrestrial radiation. The temperature difference of Darjeeling and Goalpara varies nearly inversely as the humidity of the lower station.

To conclude; I have in this paper sketched out the general system of normal wind currents of Northern India, and have shown in general terms their relations to heat and moisture, as far as they are to be gathered from existing observations. This work is almost an essential preliminary to any more detailed inquiry; but it is to be regarded as only a first rough sketch of a very important and characteristic wind-system. In many, I may say in *all* respects; it requires detailed verification. In the first place, the relations of the winds to temperature, moisture, and pressure, have to be verified by the reduction of the original data in the form of wind-roses of these several elements; the progressive diffusion of heat and vapour vertically in the hot weather has to be followed out in detail, if possible, at a well selected series of stations at heights intermediate between the present observatories and the plains, and the physical analysis which I have attempted for a vertical column of the atmosphere over Lower Bengal has to be executed for similar atmospheric columns in the drier climate of Upper India. The peculiar variations in the absorption and radiation of heat at hill stations, and on the great plateaux, which have been adverted to in the foregoing pages, have to be worked out and explained; as a preliminary to which, the present methods of observation must be re-tested and probably modified, in order to exclude the disturbing effect of convection currents. These convection currents, both on the hill sides and over the open plains, are in themselves an important object of inquiry, especially those that must be formed

between the land and sea-winds ; the upper currents, the existence of which I have inferred from various indications, await verification, wherever possible, by regular observations of the drifting of the higher clouds ; and the whole question of the diurnal variation of the winds and other meteorological elements, such as the barometric tides, remains yet for investigation. Furthermore, the causes of those persistent irregularities that characterize the monsoons of different years, to which I drew attention in the XXXIXth volume of the Journal of the Asiatic Society of Bengal, demand special inquiry, both on account of their scientific and their economic importance. And lastly, the data from other parts of India not yet treated of, or of which the treatment has been especially deficient, have to be brought together and collated with those now given. When this shall have been done, it is not improbable that the conclusions here drawn may be found in some respects to require modification. But I think that in all their leading features they are justified by the evidence adduced ; and even were it otherwise, since truth may be educed from error, but never from confusion, I might still hope that this discussion may serve a useful purpose in urging forward the work yet to be done in India, and that it may contribute something of value to the general progress of the science.

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## APPENDIX.

*Note on the Cyclones of the Bay of Bengal.*—Of seventy-three storms, notices of which I have met with in old records, and in Mr. Piddington's works, or which I have myself recorded in recent years, the distribution in the several months is as follows:—

January	...	2	May	...	17	September	...	3
February	...	0	June	...	4	October	...	20
March	...	1	July	...	2	November	...	14
April	...	5	August	...	2	December	...	3

All that have occurred between November and the end of April have been restricted to the south of the Bay; and the same is to be said of the greater part of the November storms. May and the first half of June and October with the first week of November, are the only periods in which cyclones can be said to be prevalent in the north of the Bay, though they occur occasionally in the intervening months, that is during the south-west monsoon. It will be sufficient therefore for my present purpose to consider the normal state of the winds and atmospheric pressure at these two periods of the year, and how far they help to throw light on the conditions which favour the formation of these storms.

It has been shown in the summary of Part I of the foregoing discussion that southerly winds set in on the coast of Bengal in February; at first as mere local sea-breezes, and that as the sun ascends in declination, they come from further out at sea and extend further inland. The change from north to south takes place on the Indian coast earlier than on that of Arakan. But in May southerly winds prevail over the whole of the Bay,\* and indeed, according to Maury and Cornelissen down to the line. But generally the winds are light except near the coast, and the south-west monsoon has not yet set in. The mean pressure at Port Blair, reduced to sea-level, is 29·788 inches; at Akyab 29·774; at Madras 29·747; at Calcutta 29·685; so that the mean barometric gradient is about 0·1 inch in 800 miles, or half as great as in July. There can then

\* The Port Blair observations of four years give the following result in May:—

North.	North-East.	East.	South-East.	South.	South-West.	West.	North-West.
8	13	4	26	27	146	7	17

The following table is taken from a notice of Cornelissen's work—"Route voor Stoomschepen, etc., in the Zeitschrift, d. Oesterr. Gesellschaft;" I have not seen the original work:—

*Winds in the Indian Ocean, north of 10° south latitude, in the month of May.*

80° to 90° East Longitude.

	15°-20° N.	10°-15° N.	5°-10° N.	0-5° N.	0-5° S.	5°-10° S.
North-East	...	5	7	4	3	12
East-South	...	20	20	14	16	33
South-West	...	68	59	64	49	26
West-North	...	5	9	16	25	16
Calms	...	1	5	2	7	13

90° to 100° East Longitude.

	1	7	4	5	19	10
North-East	...	1	7	4	5	19
East-South	...	10	6	12	18	29
South-West	...	65	63	67	51	21
West-North	...	17	16	11	20	16
Calms	...	7	8	6	6	15

be no question of conflicting currents being the cause of cyclones in this month, unless it be assumed that (as Sir John Herschell has suggested in the case of the West Indian storms) an upper return current strikes down with a high velocity into the southerly surface current. But there is no evidence of this in any case that I have investigated; and were this the determining cause, it would remain unexplained why cyclones are not more frequent during the south-west monsoon, when the lower current evidently at sea, and the upper therefore inferentially, have a higher velocity than in May. It would still remain to ascertain what brings the upper current down.

In October the circumstances are very different. Unsteady north-east winds do then blow on the coast of Orissa, while south-west or more frequently south-east winds prevail over the east and south of the Bay. The mean (sea-level) pressure at Port Blair is then 29·861; at Akyab 29·867; at Madras 29·855; and at Calcutta 28·859. Hence the pressure is nearly uniform around the coasts of the Bay, and, as might be expected, calms are very frequent. Here, again, although less decidedly than in May, there can hardly be any question of conflicting currents other than such as are temporary and due to local irregularities. The north-east monsoon has not yet set in, and it is to be remarked that at False Point, where north-east winds are most frequent, calms are also more frequent than in any other month in the year.

The atmosphere over the Bay is then calmer in October than in May, but storms are most frequent in the former month, and indeed, if we regard only those which disturb the northern part of the Bay, one and a half times as frequent in October as in May.\* Consequently a calm atmosphere or variable winds would appear to be a condition favouring the formation of cyclones, and this is verified by the facts of the few storms of which I have been able to trace the antecedent conditions.

I. The Calcutta storm of the 5th October 1864 appears to have originated on or about the 2nd of the month, to the west of the Northern Andaman. For several days previously the winds in the north of the Bay were variable, but on the whole southerly; at Madras they were from east-south-east; at Port Blair from south-west, then south-east, and finally west-south-west; and the pressure was lower at Port Blair than at any other station. It was not until the 2nd (that is, the day on which the storm formed) that a north-east wind set in down the Madras coast. From the readings of an uncomparated barometer at Port Blair, it would appear that the pressure at the Andamans had been lower than in Ceylon or at Madras or Calcutta, at all events since the 26th of September, perhaps earlier, and that it fell not less than 0·12 from noon of the 30th September to noon of the 1st October.

II. The Calcutta cyclone of the 2nd November 1867 was formed on the 27th October, in latitude 10° to the west of the Nicobar Islands.† For at least four days previously, the barometric pressure in this region was lower than elsewhere in or around the Bay. "It was also lower (on the 24th October certainly, and probably on the previous day also,) than on the open sea to the southward. The depression was gradually intensified up to the 27th, when it began to blow a hurricane on the northern limit of the area. It appeared that over the greater part of the Bay the pressure was nearly equable, and that the depression was local and bounded by a high barometric gradient. For many days prior to the 24th, light south-easterly winds had prevailed on the Indian coast, while in Bengal the wind was variable with a predominance of eastering. To the south, between the equator and north latitude 5°, a squally, damp, west-north-west wind blew continuously, having

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\* See report on the Calcutta Cyclone of October 1865, p. 101.

† The origin of this storm was described at length in the Proc. Roy. Soc., Vol. XVII., p. 472. I quote above some passages from this paper.

prevailed at least from the 11th of the month. On the 27th it became west-south-west, drawing round towards the area of depression. On the 24th and 25th a north-east wind set in Bengal and down the west of the Bay, displacing the south-east wind, which, however, continued to be felt in the immediate neighbourhood of the Nicobars, and the cyclone vortex was formed by the indraught of these three currents to the pre-existing area of barometric depression.

III. "The storm of the 13th and 17th\* May 1869 originated near Cape Negrais on the first of these days. A south-west breeze had been blowing pretty steadily over the greater part of the Bay for some days before, the mean direction being south-south-west in the north of the Bay, south-west in the middle, and west-south-west in the south." Only "in the neighbourhood of the Andamans, Cape Negrais, and Rangoon, a northerly or north-westerly wind was felt occasionally during the ten days previous, but it was unaccompanied by any fall of temperature, and would seem to have been a local deflection of the south-west current." "Some observations of pressure in the neighbourhood of Cape Negrais would seem to indicate the existence of a slight barometric depression in the Gulf of Martaban, and to the west and north of Cape Negrais, but the instruments were not sufficiently trustworthy to establish the fact in a satisfactory manner."

IV. The storm of the 5th and 10th June† of the same year was apparently formed in the middle of the Bay, in about 16° north latitude. At Port Blair the wind had been steady from south and south-west for two or three days; at Chittagong and Akyab, southerly, with alternations of land and sea breezes; at Saugor Island, south; at False Point, south-east; and a steamer crossing the head of the Bay from Calcutta to Akyab had a steady south-east breeze. Around the coasts the pressure was lowest at Saugor Island on the 4th, when it was 0·1 below that at Port Blair, i.e., rather less than the normal difference in this month. On the 5th the difference was reduced one-half of this, but in the middle of the Bay, when the storm originated, the barometer stood at more than 0·2 inches lower than at Saugor Island, and there is evidence of the winds beginning on that day to curve in around the local depression.

V. The cyclone of the 7th and 8th October of the same year‡ commenced in the northern part of the Bay, on the morning of the former day. At Port Blair the wind had been steady from the south-west for several days, and the barometer had not varied more than ·03 inches on the mean of the day, from the 2nd to the 6th. At Akyab the barometric change had been but little greater and the wind had been light from south-south-east, with one or two changes to north and east, for a few hours, which were probably due to local causes. On the 6th it was steady from between south-south-east and south-west, blowing moderate to fresh. At Saugor Island the wind was light, and from the south up to midnight of the 5th, after which a light wind set in from east-north-east and continued without much change till sunset of the 6th. At False Point the barometer had been steady, and the wind south-east or east. In the south of the Bay the wind had been from west or west south-west for several days, and the weather squally; this appears to be always the case before a cyclone.

VI. The Vizagapatam storm of the 5th November 1870§ probably commenced on the 1st of the month to the west of the Andamans. During the last four days of October a considerable change had taken place in the distribution of atmospheric pressure over the Bay. On the 28th it had

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\* Meteorological Report for Bengal, 1869, p. 102.

† Ditto ditto, 1869, p. 103.

‡ Ditto ditto, 1869, p. 107.

§ Ditto ditto, 1870, p. 116.

been lowest at Vizagapatam and Port Blair; and at Madras to the southward and at all the coast stations around the north of the Bay, only about 0·05 in. higher than at Vizagapatam. On the three following days the Madras pressure remained almost unchanged, but a general rise took place to the north-west, which brought the pressure at Vizagapatam up to an equality with that of Madras; and that of Saugor Island and False Point above all other stations. At the same time a fall of 0·1 inch took place at Port Blair, which reduced the pressure at that station to about 0·15 in. below that in the north-west of the Bay. Over the north of the Bay, as far down as  $18^{\circ}$  or  $19^{\circ}$  on the Indian coast, and down to Port Blair on the other side, the wind was from north and north-east. At Vizagapatam it was variable, and at Madras chiefly from the westward. On the open sea to the southward, the westerly monsoon, with its characteristic squally weather, prevailed; but over a triangular area, extending across the Bay between Coconada, Madras, and Rangoon, calms and variable winds had prevailed for two weeks previously, and it was along the middle of this calm belt that the cyclone subsequently took its course.

These instances show at least that the existence of opposite currents antecedently to the formation of a cyclone is by no means an essential condition. In the case of storms I, IV, and V, no northerly or north-easterly wind was felt in the north-west of the Bay, until the day that the storm vortex was found, and the barometric depression which, in the first case certainly, and probably in the others pre-existed, must have been the cause both of the north-east wind and the cyclone. And in the other cases mentioned, the north-east wind in no case blew further south than the place of the storm's origin.

It is generally difficult to ascertain the exact barometric pressure at the place at which a storm originates for a week or ten days before the cyclone is formed; since such data can be obtained only from such ships as may subsequently arrive in Calcutta, if even from them, and in most cases the instruments in use on board ships are not read with that accuracy that is requisite to establish the existence of a depression of less than about 0·1 inch (a large amount in tropical seas), and their inherent error is generally unknown; but such data as I have obtained have led me to infer that, as in the case of storm II, an area of barometric depression is, as a rule, formed several days before the cyclone is generated; and *a priori* considerations would lead us to expect that such must be the case, producing a convergence of the air around. When such a convergence has once been established, the formation of a cyclone is easily explained from known physical laws.

I must therefore conclude that the views put forward by Mr. Meldrum with respect to the formation of storms in the South Indian Ocean,\* viz. that they are produced between parallel currents flowing in opposite directions, do not hold good in the case of the Bay of Bengal. I infer that a calm state of the atmosphere, or one in which the winds are light and variable over the open sea, is a condition favorable to the formation of these storms, and that a second condition is a high or moderately high temperature. The consequence of this collocation will be the production and ascent of a large quantity of vapour, which will be condensed with the liberation of its latent heat over the place of its production, instead of being carried away to some distant region. If this state of things last for some days, the atmospheric pressure will be locally lowered, causing or tending to cause, an indraught of air towards the place of minimum pressure. In order that a cyclone may ensue one further condition appears to be essential. It was pointed out in a paper on the origin of the November cyclone, 1867, published in the Proceedings of the Royal Society,† that most of the storms of the Bay of Bengal originate along a line running from south to north by the

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\* Proceedings, Meteorological Society of London, February 1869.

† Proceedings, Royal Society, No. 113, 1869, p. 479.

Nicobars, Andamans, and the islands of the Arakan Coast. Some, such as those of the 5th and 10th June and the 7th and 8th October 1869 (*supra* IV, V), also a storm that occurred during the present year on the 30th June and 1st July,\* originate about the middle of the Bay. But I do not know of a single case in which a cyclone has been actually formed in the north-west of the Bay, or under the lea of the Madras coast, although more than one case has been recorded in which most of the requisite conditions were fulfilled, and in which for some days there has seemed reason for apprehending one.† These facts, I think, find their explanation in another fact, surmised by Colonel Gastrell and myself as a probable local law in 1865,‡ and verified in the case of every storm I have yet investigated, (where sufficient evidence has been forthcoming,) viz. that the formation of a cyclone is determined by an inrush of a saturated stormy current from the south-west or west-south-west. Now, under the lea of the Madras coast or in the north-west of the Bay, any wind coming from this direction must pass over the peninsula, a course which would drain it to a great extent of its vapour, while its free passage would be enormously impeded by friction and the irregularities of the land surface. But in the eastern half of the Bay no such impediments present themselves to its free access, and its high velocity and abundant vapour seem to be the determining conditions of the formation of cyclones.

I would especially guard myself against being supposed to extend the above views, *mutatis mutandis*, to the case of the South Indian Ocean, or indeed any area other than that I am specially dealing with. Doubtless, it will be found that in each region subject to cyclones, the determining conditions present local modifications; and the best way to arrive at a general theory of the formation of cyclonic storms will be to ascertain the local conditions as accurately as possible in each case by independent study, as Mr. Meldrum has done in the South Indian Ocean, and as I have here attempted for the Bay of Bengal. It will then be easy to eliminate all that is merely local, and to establish general laws by a comparison of the results so obtained.

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\* Described by Mr. W. G. Willson in a report to the Government of Bengal.

† See the Bengal Meteorological Reports for 1870, p. 115, and 1871, p. 124. Another case occurred during the present year on the 26th October.

‡ Report on the Calcutta Cyclone of 1864, p. 105, &c.



TABLE I.—WIND DIRECTIONS AND VELOCITIES.

PUNJAB.  
I.—Rawul Pindée.

	OBSERVED.						PER CENT.						RESULTANT.									
	Years.	N.	NE.	E.	SE.	S.	SW.	W.	NW.	Calm.	N.	NE.	E.	SE.	S.	SW.	W.	NW.	Calm.	Per cent.	Direction.	
January ...	3	13	8	39	7	8	5	94	12		7	4	21	4	4	4	3	51	6		31	N 79 W
February ...	3	8	6	28	8	8	8	98	6		5	3	16	5	5	5	5	58	3		41	S 88 W
March ...	3	11	9	51	2	13	7	84	8		6	5	28	1	7	4	4	45	4		19	N 84 W
April ...	3	7	7	33	8	11	3	101	9		4	4	18	5	6	2	5	56	5		37	W
May ...	3	25	3	33	2	9	10	85	19		13	2	18	1	5	5	4	46	10		39	N 72 W
June ...	3	17	5	64	8	12	6	61	7		9	3	36	4	4	7	3	34	4		3	N 33 W
July ...	3	12	6	110	6	6	7	34	1		7	3	60	3	3	4	4	19	1		43	N 89 E
August ...	4	18	11	64	49	19	15	66	3		7	5	26	20	8	6	2	27	1		19	S 37 E
September ...	4	15	15	66	25	24	21	66	8		6	6	28	10	10	9	28	48	3		11	S 17 E
October ...	4	9	6	29	17	27	24	118	17		3	2	12	7	11	10	48	7	7		43	S 73 W
November ...	4	15	6	22	14	17	68	73	6		6	6	10	9	6	7	28	3	3		35	S 63 W
December ...	3	11	12	26	2	3	10	103	17		6	7	14	1	2	5	56	9	9		31	N 69 W
Year ...	...	...	...	...	...	...	...	...	...		6.5	4	24	5.5	6	7	42	5	5		...	.....

## II.—Dera Ishmail Khan.

January ...	...	33	43	10	11	18	9	25	41	17	23	5	6	9	5	13	22	26	N 10 W
February ...	...	3	47	8	9	7	10	19	42	16	28	5	5	4	6	11	25	41	N 7 W
March ...	...	3	32	24	19	11	6	16	37	17	22	13	10	6	3	9	20	33	N 18 E
April ...	...	3	37	19	26	18	27	6	25	12	21	11	14	10	15	3	14	13	N 66 E
May ...	...	3	54	42	25	12	26	5	7	8	29	23	13	7	13	3	4	38	N 81 E
June ...	...	3	57	36	28	21	14	3	9	5	31	21	16	12	8	2	5	43	N 88 E
July ...	...	3	57	37	33	25	24	...	4	2	31	20	18	14	13	...	2	45	S 77 E
August ...	...	4	54	52	95	19	29	...	3	2	21	20	37	7	12	...	1	57	S 66 E
September ...	...	4	61	64	68	27	20	1	1	2	24	26	27	11	8	...	1	58	S 74 E
October ...	...	4	85	31	43	25	20	9	13	12	33	12	17	10	8	3	5	37	N 71 E
November ...	...	4	53	22	34	22	25	21	28	13	23	9	14	9	11	4	12	15	N 46 E
December ...	...	4	57	27	20	28	11	29	48	12	23	11	8	11	4	9	19	22	N 11 E
Year ...	...	...	...	...	...	...	...	...	...	10	26	15	15	9	9	5	11	...	.....

TABLE I.—WIND DIRECTIONS AND VELOCITIES.—(Continued.)

PUNJAB.

III.—Mooltan.

	OBSERVED.											PER CENT.							RESULTANT.			
	Years.	N.	NE.	E.	SE.	S.	SW.	W.	NW.	Calm.	N.	NE.	E.	SE.	S.	SW.	W.	NW.	Calm.	Per cent.	Direction.	
January ...	3	46	17	6	11	7	20	5	55		27	10	4	7	4	12	7	3	33		45	N 25 W
February ...	3	42	29	7	20	17	12	4	30		26	18	4	13	11	7	2	2	19		18	N 10 E
March ...	2	12	34	2	12	7	15	2	38		10	28	15	10	6	12	1	15	31		30	N 7 W
April ...	3	17	27	7	23	12	36	4	48		10	15	4	13	7	21	2	2	28		14	N 49 W
May ...	3	15	21	5	14	13	63	13	35		8	12	3	8	7	35	7	7	20		30	S 76 W
June ...	3	5	24	4	18	26	81	4	16		3	13	2	10	15	46	2	9	6		41	S 31 W
July ...	3	9	21	...	20	16	100	1	10		5	12	...	11	9	56	1	7	8		49	S 35 W
August ...	3	19	28	5	22	30	53	12	14		10	15	3	12	16	29	7	4		21	S 29 W	
September ...	3	8	5	2	10	48	101	1	8		4	12	1	6	26	55	3	18		31	S 31 W	
October ...	4	27	31	1	16	34	83	18	46		11	12	...	6	13	33	7	24		31	S 73 W	
November ...	3	17	31	1	20	17	40	11	43		95	17	1	11	95	22	6	21		19	N 72 W	
December ...	4	31	60	10	24	14	34	5	49		14	26	4	11	6	15	2	2		23	N 6 E	
Year ...	...	...	...	...	...	...	...	...	...		12	15	2	10	11	29	3	3	18	†	...	.....

IV.—Lahore.

January ...	...	3	23	23	11	10	4	13	37	62	13	13	6	5	2	7	20	34	46	N 41 W
February ...	...	3	20	26	23	5	1	5	30	60	12	15	13	3	1	3	18	35	47	N 23 W
March ...	...	3	33	39	12	9	4	6	35	49	18	21	6	5	2	3	19	26	43	N 20 W
April ...	...	3	15	25	18	4	...	9	48	60	8	14	10	2	...	5	27	34	49	N 41 W
May ...	...	2	10	27	12	5	3	11	10	33	9	24	11	4	1	10	9	30	35	N 9 W
June ...	...	2	2	17	18	13	1	27	12	24	2	14	15	11	3	22	10	20	10	N 48 W
July ...	...	2	2	27	20	30	4	26	4	10	2	22	16	25	4	17	3	8	28	S 63 E
August ...	...	3	5	40	38	45	7	32	5	12	3	22	21	9	4	18	26	6	35	S 72 E
September ...	...	3	9	34	15	15	4	32	47	22	5	19	9	11	3	6	14	12	21	N 72 W
October ...	...	4	24	35	22	25	7	15	32	74	10	15	9	11	2	6	14	32	31	N 24 W
November ...	...	4	19	38	20	25	4	11	40	82	8	16	8	10	2	5	17	34	36	N 29 W
December ...	...	4	42	42	28	12	...	8	29	90	17	17	11	5	...	3	11	36	50	N 14 W
Year ...	...	...	...	...	...	...	...	...	...	...	9	18	11	10	2	10	15	25	...	....

GANGETIC VALLEY.

I.—Roorkee.

	OBSERVED.										PER CENT.			RESULTANT.		MEAN DAILY MOVEMENT.	
	Years.	N.	NE.	E.	SE.	S.	SW.	W.	NW.	Direction.	Direction.	Direction.	Direction.	Direction.	Direction.	Years.	Miles.
January	...	1	10	8	32	7	34	9	125	209	...	2	2	8	2	2	40.2
February	...	7	24	17	26	5	14	27	115	161	2	4	7	7	29	4	47.0
March	...	7	21	9	19	17	21	41	124	184	2	4	7	25	29	4	51.5
April	...	7	25	8	59	12	29	42	85	145	1	7	10	14	28	3	64.7
May	...	7	9	8	115	24	29	31	98	116	2	7	7	27	21	3	73.8
June	...	7	7	20	93	24	21	25	92	119	2	6	6	22	22	4	72.7
July	...	7	3	16	167	16	19	15	32	144	1	4	3	34	7	4	53.4
August	...	7	4	14	152	7	18	17	52	156	1	3	4	23	12	4	38.1
September	...	7	6	12	84	6	21	15	92	168	1	4	4	3	22	4	27.3
October	...	7	18	10	85	18	12	12	64	219	...	2	3	7	14	4	18.2
November	...	7	7	2	63	8	8	8	48	273	1	...	2	4	11	5	19.2
December	...	7	4	3	49	...	15	28	91	231	1	3	6	15	21	6	25.4
Year	...	...	...	...	...	...	...	...	...	...	1.1	3.7	5.2	...	19.8	...	...

II.—Agra.

January	...	36	14	24	5	10	8	80	24	90	12	5	8	2	3	27	...
February	...	6	21	10	4	11	7	106	33	74	11	7	7	1	2	36	...
March	...	6	33	10	18	18	6	111	48	75	15	6	3	3	2	37	...
April	...	7	33	31	24	20	7	83	64	20	7	7	9	5	20	...	...
May	...	6	22	35	21	24	9	110	45	31	8	6	10	6	9	...	...
June	...	6	31	47	16	9	26	85	43	40	8	5	14	3	13	...	...
July	...	7	37	89	21	12	19	46	33	90	8	13	23	5	8	...	...
August	...	7	52	68	43	24	42	45	18	129	2	6	17	11	12	...	...
September	...	7	30	66	13	4	18	65	53	116	6	8	18	3	8	...	...
October	...	7	24	12	13	21	22	109	27	156	6	5	3	1	5	...	...
November	...	7	9	18	18	26	35	73	26	164	5	2	5	5	6	...	...
December	...	7	29	39	23	15	19	91	41	146	5	7	9	4	21	...	...
Year	...	...	...	...	...	...	...	...	...	...	7.7	7.2	10.5	4.8	23.3	...	...

TABLE I.—WIND DIRECTIONS AND VELOCITIES.—(Continued.)

GANGETIC VALLEY.

III.—Benares.

	OBSERVED.										PER CENT.						RESULTANT.		MEAN DAILY MOVEMENT.					
	Years.	N.	N.E.	E.	S.E.	S.	S.W.	W.	N.W.	Calm.	N.	N.E.	E.	S.E.	S.	S.W.	W.	N.W.	Calm.	Per cent.	Direction.	Years.	Miles.	
January ...	6	12	25	35	22	4	37	112	52	40	4	7	10	7	1	11	33	33	15	12	33	N 75 W	3	55.6
February ...	6	8	19	43	18	...	40	136	36	30	2	6	13	5	...	12	41	37	11	10	37	N 87 W	3	73.3
March ...	6	14	14	48	15	7	31	132	65	13	4	4	14	5	2	9	39	38	19	4	38	N 76 W	3	66.2
April ...	6	21	22	29	34	3	30	112	75	16	6	6	8	10	1	9	33	37	22	5	37	N 70 W	3	62.9
May ...	7	30	61	85	13	1	33	85	76	13	8	15	22	3	...	8	22	21	19	3	24	N 14 W	3	87.3
June ...	7	15	54	88	20	9	36	81	65	12	4	14	23	6	2	10	21	17	3	3	14	N 13 W	3	95.2
July ...	7	9	39	114	26	15	58	91	23	14	2	10	29	7	4	15	23	6	4	4	6	S 28 E	3	73.4
August ...	7	9	33	99	32	10	47	101	38	36	2	8	24	8	2	11	27	9	9	6	4	S 67 W	3	69.7
September ...	7	14	48	103	27	14	24	74	27	35	2	13	29	8	4	7	21	8	8	9	5	N 69 E	3	58.3
October ...	7	13	28	60	19	7	31	120	68	35	3	7	16	6	2	8	31	18	9	9	27	N 68 W	3	60.9
November ...	7	26	28	30	13	12	33	123	70	45	7	7	8	3	3	9	32	19	12	12	38	N 69 W	3	25.0
December ...	6	18	19	44	4	4	8	136	69	15	6	6	14	1	1	2	43	22	5	16	N 62 W	3	34.2	
Year ...	...	...	...	...	...	...	...	...	...	...	4.3	8.6	17.5	5.8	1.8	9.3	30.5	15.4	6.8	...	...	...	...	

IV.—Patna.

IV.—Patna.

	A.—OBSERVED. CALMS NOT RECORDED.										B.—OBSERVED. CALMS RECORDED.									
	Years.	N.	NE.	E.	SE.	S.	SW.	W.	NW.	Calm.	Year.	N.	NE.	E.	SE.	S.	SW.	W.	NW.	Calm.
January ...	4	24	26	23	16	13	65	144	121	p	1	1	5	2	1	...	2	12	11	90
February ...	4	32	34	32	14	11	49	96	124	p	1	1	6	7	5	1	4	12	10	70
March ...	4	40	29	25	15	7	57	94	171	p	1	1	...	...	...	...	3	27	29	64
April ...	4	44	74	57	28	2	20	42	148	p	1	1	15	...	5	...	4	19	19	44
May ...	4	71	119	82	37	1	18	26	80	p	1	1	...	13	5	...	2	5	10	45
June ...	4	61	105	96	54	2	19	28	54	p	1	1	19	19	6	1	...	...	...	74
July ...	4	41	72	130	65	3	37	28	58	p	1	1	13	13	2	1	...	2	...	88
August ...	3	5	38	55	59	38	47	38	30	p	1	1	1	13	9	8	6	6	4	41
September ...	4	14	62	111	116	4	26	20	16	p	1	1	2	11	22	18	...	...	2	65
October ...	4	20	61	56	60	19	42	50	68	p	1	1	6	10	5	...	7	...	9	79
November ...	4	50	63	30	13	9	20	60	115	p	1	1	2	6	4	1	...	3	11	8
December ...	4	23	29	34	20	7	39	111	148	p	1	...	...	4	3	...	3	8	7	98

GANGETIC VALLEY.

IV.—Patna.

PER CENT.										RESULTANT.		MEAN DAILY MOVEMENT.	
N.	NE.	E.	SE.	S.	SW.	W.	NW.	Calm.	Per cent.	Direction.	Years.	Miles.	
January ... ..	1	2	1	1	4	9	8	73	15	N 71 W	2	64.6	
February ... ..	2	4	2	1	4	10	12	61	16	N 60 W	2	72.8	
March... ..	4	2	1	1	5	13	20	52	30	N 61 W	2	96.2	
April ... ..	5	12	4	...	3	9	21	37	24	N 12 W	2	144.2	
May ... ..	10	18	5	...	2	4	11	37	30	N 33 E	2	138.7	
June ... ..	5	11	5	...	1	2	4	62	19	N 57 E	2	90.3	
July ... ..	2	6	4	...	2	2	4	71	11	N 67 E	2	81.2	
August ... ..	1	8	15	8	9	7	6	33	14	S 41 E	2	81.1	
September ... ..	2	8	15	...	2	2	2	54	26	S 82 E	2	84.4	
October ... ..	3	6	5	2	4	4	7	64	4	N 13 E	2	50.1	
November ... ..	4	6	3	1	3	7	10	64	12	N 37 W	2	51.7	
December ... ..	1	2	1	...	2	6	7	79	9	N 69 W	2	34.4	
Year ... ..	3.3	7.1	5	1.2	3.4	6.2	9.3	57.3	.....	.....	.....	.....	

TABLE I.—WIND DIRECTIONS AND VELOCITIES.—(Continued.)

RAJPOOTANA.

*I.—Beawur and Ajmere.*

	OBSERVED.										PER CENT.						RESULTANT.		MEAN DIURNAL MOVEMENT.					
	Years.	N.	N.E.	E.	S.E.	S.	S.W.	W.	N.W.	C <sup>o</sup> E.	N.	N.E.	E.	S.E.	S.	S.W.	W.	N.W.	C <sup>o</sup> E.	Direction.		Years.	Miles.	
																				E <sup>o</sup> N.	S <sup>o</sup> W.			
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
January	7	36	59	34	52	23	41	31	28	54	10	16	10	15	11	6	11	9	8	15	10	N 62 E	...	...
February	7	31	22	37	24	27	46	62	26	47	10	7	12	7	14	8	14	19	8	15	14	S 75 W	...	...
March	7	29	30	11	41	29	72	53	16	20	9	10	4	8	24	9	24	17	6	7	21	S 46 W	...	...
April	6	22	7	6	21	29	113	87	44	28	6	2	2	6	32	8	32	24	12	8	52	S 69 W	...	...
May	7	12	6	5	13	16	200	101	14	9	3	2	1	4	4	53	27	4	2	2	73	S 59 W	...	...
June	7	7	18	7	10	18	188	111	9	20	2	5	2	2	5	48	29	2	2	5	67	S 60 W	...	...
July	7	1	14	8	14	15	168	142	14	23	...	3	2	3	4	42	36	3	3	6	69	S 63 W	...	...
August	7	8	32	16	13	7	168	115	29	33	2	8	4	3	1	40	27	7	8	8	53	S 68 W	...	...
September	7	5	26	5	15	10	111	193	20	30	1	6	1	4	2	27	47	5	7	7	84	S 68 W	...	...
October	7	22	47	5	16	8	79	156	15	65	5	11	1	4	2	19	38	4	5	16	48	S 87 W	...	...
November	6	40	44	35	14	21	31	65	15	63	12	13	11	4	6	9	20	5	5	20	11	N 37 W	...	...
December	6	48	44	40	26	50	26	30	22	51	14	13	12	8	15	8	9	6	6	16	8	N 73 E	...	...
Year	...	...	...	...	...	...	...	...	...	...	6	8	5	6	6	6	27	25	6	10	...	.....	...	...

*II.—Jhansi.*

January	3	14	26	34	9	12	7	39	38	7	8	14	18	5	6	4	21	20	4	...
February	3	3	15	20	11	16	1	51	23	1	8	9	13	7	10	33	33	15	1	...
March	4	21	14	42	18	37	3	62	13	3	13	6	19	17	6	28	28	6	1	...
April	5	22	13	40	16	24	21	95	32	21	39	4	13	8	32	11	32	7	1	...
May	5	8	30	47	16	11	26	92	86	4	26	9	15	5	8	27	27	11	7	...
June	6	25	30	57	33	8	44	98	51	23	37	8	15	2	13	14	14	6	1	...
July	5	8	28	41	14	11	57	112	26	13	57	9	13	4	18	8	27	4	4	...
August	6	18	19	86	14	26	46	103	63	5	23	8	23	7	13	28	14	5	17	...
September	5	57	23	25	12	17	5	106	40	15	5	5	8	6	4	13	13	5	38	...
October	5	31	37	33	11	23	13	105	37	17	10	12	11	4	8	34	11	6	28	...
November	6	44	18	58	8	26	7	107	40	16	14	6	18	2	33	25	12	1	53	...
December	5	35	43	64	22	15	10	78	48	3	11	13	20	7	5	15	15	20	8	...
Year	...	...	...	...	...	...	...	...	...	...	...	9	16	5	7	30	14	3	...	...

CENTRAL INDIA.  
I.—Jubbulpore.

	OBSERVED.										PER CENT.						RESULTANT.		MEAN DIURNAL MOVEMENT.				
	Years.										N.	NE.	E.	SE.	S.	SW.	W.	NW.	Calm.	Per cent.	Direction.	Years.	Miles.
January ...	3	49	39	3	14	26	13	12	25	5	26	21	2	8	14	7	6	13	3	27	N 6 W	2	61.3
February ...	3	34	18	4	17	26	19	16	20	9	21	11	2	10	16	12	10	12	6	11	N 58 W	2	50.7
March ...	3	26	18	7	14	40	16	43	21	...	14	10	4	8	22	9	23	11	...	22	S 79 W	2	83.3
April ...	3	28	16	8	5	22	14	51	27	8	16	9	4	3	12	8	28	15	4	34	N 68 W	3	93.1
May ...	3	24	11	2	7	13	25	63	39	2	13	6	1	4	7	13	24	21	1	41	N 76 W	3	123.1
June ...	3	5	4	5	1	5	40	97	22	1	3	2	3	1	3	22	54	12	1	74	S 85 W	3	145.7
July ...	3	4	4	1	...	9	32	115	21	1	2	2	1	...	5	17	61	12	1	80	S 86 W	3	132.0
August ...	3	3	3	1	7	12	26	116	17	1	2	2	1	4	6	14	62	9	1	75	S 83 W	3	123.0
September ...	3	32	15	6	11	12	13	62	24	5	18	8	3	6	7	7	35	13	3	39	N 64 W	3	92.0
October ...	3	39	31	16	4	21	23	30	18	4	21	17	8	2	11	12	17	10	2	16	N 29 W	3	52.7
November ...	3	49	41	14	17	24	15	5	8	7	27	23	8	10	13	8	3	4	4	28	N 42 E	2	47.1
December ...	3	38	50	6	26	26	16	10	11	3	20	27	3	14	14	9	5	6	2	21	N 50 E	3	55.8
Year ...	...	...	...	...	...	...	...	...	...	...	15	12	3	6	11	12	27	12	2	...	.....	...	.....

II.—Nagpore.

January ...	3	15	52	51	16	13	13	8	6	12	8	28	27	9	7.5	7.5	4	3	6	43	N 74 E	2	70.1
February ...	3	18	24	30	17	21	12	10	22	9	11	15	18	10	13	7	6	14	6	16	N 70 E	2	85.8
March ...	3	24	16	32	12	34	27	20	22	2	13	8	17	6	18	14	11	12	1	6	S 15 W	2	99.9
April ...	3	3	11	17	11	23	18	29	37	...	18	6	10	6	13	10	16	21	...	24	N 59 W	2	116.4
May ...	3	55	7	9	2	13	13	32	49	1	29	4	5	4	6	7	17	27	1	47	N 40 W	3	162.1
June ...	3	17	5	4	...	14	27	48	60	4	9	3	2	1	8	15	26	33	2	58	N 74 W	2	163.4
July ...	3	7	4	3	...	12	50	82	44	2	4	2	1	...	1	26	42	23	3	73	N 89 W	3	156.5
August ...	3	9	4	5	3	12	25	66	56	6	5	2	3	2	6	13	36	30	3	62	N 80 W	3	122.9
September ...	3	24	10	14	10	11	30	30	58	3	13	5.5	8	5.5	6	11	17	32	2	42	N 49 W	3	120.4
October ...	3	35	69	28	13	3	8	2	22	6	19	37	15	7	2	4	1	12	3	56	N 38 E	3	88.7
November ...	3	22	55	63	19	5	3	3	5	6	12	30	34	10	3	3	2	3	3	62	N 68 E	3	71.4
December ...	3	19	55	54	28	10	7	2	4	7	10	30	29	15	5	4	1	2	4	57	N 76 E	3	59.7
Year ...	...	...	...	...	...	...	...	...	...	...	12	14	14	6	7	10	15	18	3	...	.....	...	...

TABLE I.—WIND DIRECTIONS AND VELOCITIES.—(Continued.)  
WESTERN BENGAL AND ORISSA.  
*I.—Hasareebagh.*

OBSERVED.													PER CENT.					RESULTANT.		MEAN DIURNAL MOVEMENT.		
Years.	N.	NE.	E.	SE.	S.	SW.	W.	NW.	Calm.	N.	NE.	E.	SE.	S.	SW.	W.	NW.	Calm.	Per cent.	Direction.	Years.	Miles.
3	32	12	8	18	33	26	113	139	...	8	3	2	5	9	7	30	36	...	60	N 70 W	3	98.0
3	27	5	5	14	25	38	111	110	...	8	2	2	4	7	11	33	33	...	58	N 77 W	3	131.4
3	26	3	7	12	32	68	113	111	...	7	1	2	3	9	18	30	30	...	61	N 85 W	3	147.6
3	24	18	26	35	41	52	70	92	...	7	5	7	10	11	14	20	26	...	32	S 89 W	3	168.4
3	40	14	27	59	77	36	42	62	...	11	4	8	16	22	10	12	17	...	17	S 36 W	3	187.3
3	15	21	31	72	94	49	34	34	...	4	4	6	9	20	28	13	9	...	35	S 6 W	3	184.6
3	12	15	33	71	86	36	46	38	4	3	4	17	19	23	10	13	10	...	31	S 13 E	3	152.3
3	16	15	36	45	54	48	113	44	...	4	4	10	12	15	13	30	12	...	32	S 58 W	3	131.9
3	32	25	79	90	61	29	25	22	...	8	7	22	25	17	8	7	6	...	36	S 50 E	3	129.2
3	48	19	18	38	36	35	72	108	...	13	5	5	10	10	9	19	29	...	34	N 66 W	3	103.5
3	59	25	10	2	22	26	85	130	...	16	7	3	1	6	7	24	36	...	62	N 50 W	3	91.1
3	37	13	6	14	19	38	104	141	...	10	3	2	4	5	10	23	38	...	62	N 66 W	3	92.7
...	...	...	...	...	...	...	...	...	...	8	4	7	11	13	11	22	24	...	...	.....	...	.....
January	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
February	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
March	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
April	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
May	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
June	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
July	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
August	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
September	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
October	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
November	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
December	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Year	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...

II.—Cuttack.

January	3	33	51	94	49	62	21	22	47	...	...	9	13	25	13	16	6	6	12	...	25	S 68 E	1	38.6
February	3	23	34	57	35	88	39	38	25	...	...	7	10	17	10	26	12	11	7	...	23	S 18 E	1	66.7
March	3	12	15	31	61	149	38	52	23	...	...	3	4	8	16	39	14	14	6	...	47	S 2 W	1	85.1
April	3	7	22	18	34	187	50	25	11	...	...	2	6	7	10	53	14	7	3	...	63	S 3 W	2	123.3
May	3	9	13	26	34	257	25	6	5	...	...	2	3	7	9	69	7	2	1	...	75	S 7 E	2	134.8
June	3	6	8	30	38	151	70	43	16	...	...	2	2	2	10	42	20	12	4	...	56	S 8 W	2	134.8
July	3	15	5	7	19	129	85	76	34	...	...	4	1	2	5	35	23	21	9	...	52	S 39 W	2	94.2
August	3	9	9	20	34	92	73	81	52	...	...	4	2	5	10	25	20	22	14	...	54	S 44 W	2	78.2
September	3	3	44	61	29	106	36	33	26	...	...	6	12	17	8	30	10	9	8	...	25	S 24 E	2	78.
October	3	56	87	55	42	39	19	21	46	...	...	15	24	15	11	11	5	6	13	...	30	N 51 E	2	56.
November	3	108	56	23	9	15	17	49	82	...	...	30	16	6	2	4	5	14	23	...	51	N 16 W	2	35.9
December	3	56	46	39	24	14	12	46	65	...	...	19	15	13	8	5	4	15	21	...	27	N 1 W	2	34.8
Year	...	...	...	...	...	...	...	...	...	...	...	8	9	11	9	30	11	12	10	...	...	.....	...	...

Cuttack, 1 year—(calms recorded.)

ix

	OBSERVED.										PER CENT.						RESULTANT.				
	Years.	N.	NE.	E.	SE.	S.	SW.	W.	NW.	$\frac{E}{S}$ $\frac{W}{O}$	N.	NE.	E.	SE.	S.	SW.	W.	NW.	Calm.	Per cent.	Direction.
...	1	7	19	19	20	34	11	8	1	5	6	15	15	16	28	9	6	1	4	37	S 40 E
January	1	5	16	5	13	35	19	6	5	12	5	14	4	11	30	17	5	4	11	33	S 3 E
February	1	3	11	10	11	34	33	7	4	11	2	9	8	9	27	27	6	3	9	42	S 8 W
March	1	3	5	3	7	30	25	3	44	...	2	3	4	2	25	21	2	37	...	50	N 41 W
April	1	...	7	8	15	53	36	3	2	...	...	6	6	12	43	29	2	2	...	67	S 4 W
May	1	5	4	1	6	27	27	18	2	...	...	4	4	7	30	30	20	6	...	57	S 36 W
June	1	1	2	1	22	26	34	21	8	9	1	2	1	18	21	27	17	6	7	55	S 29 W
July	1	5	2	5	6	17	49	35	8	1	1	8	2	5	14	39	28	6	1	68	S 53 W
August	1	1	2	3	9	35	27	4	2	23	6	8	2	8	29	23	3	2	19	40	S 10 W
September	1	7	10	...	2	7	14	6	9	59	11	10	...	2	6	11	5	7	48	15	N 46 W
October	1	14	12	...	2	7	6	8	13	34	15	14	7	7	7	5	7	10	28	18	N 16 E
November	1	18	17	8	8	9	6	8	6	10	19	29	15	11	2	6	3	5	10	45	N 49 E
December	1	23	36	19	14	3	7	4	...	12	6	10	5	9	22	20	9	7	12	.....	.....
Year	...	...	...	...	...	...	...	...	...	...	6	10	5	9	...	...	...	7	12	.....	.....

III.—False Point.

Years.	N.	NE.	E.	SE.	S.	SW.	W.	NW.	$\frac{E}{S}$	$\frac{W}{O}$	N.	NE.	E.	SE.	S.	SW.	W.	NW.	Calm.	Per cent.	Direction.
January	44	140	47	29	25	27	11	13	21	12	39	13	13	8	7	8	3	4	6	44	N 55 E
February	3	51	31	34	23	92	35	32	12	6	15	9	4	10	8	28	10	10	4	16	S 37 W
March	3	27	13	22	28	162	60	21	4	4	8	4	1	6	14	46	17	6	1	51	S 52 W
April	3	9	3	13	47	228	23	11	2	2	2	1	1	4	19	66	7	3	1	77	S 42 W
May	3	5	5	15	69	247	12	8	...	1	1	1	1	10	10	51	7	2	...	83	S 35 W
June	3	3	6	38	37	173	57	16	13	...	1	2	...	5	9	40	35	5	4	69	S 42 W
July	3	2	1	17	33	140	123	32	2	...	4	...	...	6	7	34	23	9	4	76	S 63 W
August	3	15	7	22	25	123	85	63	15	3	12	5	6	12	8	38	11	7	4	54	S 72 W
September	3	43	16	41	29	132	38	23	9	5	28	8	8	12	8	9	6	7	2	34	S 40 W
October	3	102	29	42	28	32	23	27	39	10	39	7	3	12	3	4	3	11	1	21	N 53 E
November	3	142	23	21	11	15	9	37	24	24	40	8	6	6	3	2	2	13	7	58	N 28 E
December	3	139	30	18	11	7	...	47	...	21	39	8	5	5	3	6	11	8	4	57	.....
Year	3	...	...	...	...	...	...	...	...	7	16	5	...	7	9	33	...	8	4	...	...

TABLE I.—WIND DIRECTIONS AND VELOCITIES.—(Continued.)

GANGETIC DELTA.  
I.—Saugor Island.

	OBSERVED.										PER CENT.								RESULTANT.		MEAN DIURNAL MOVEMENT.		
	Years.		N.	NE.	E.	SE.	S.	SW.	W.	NW.	Dir.	N.	NE.	E.	SE.	S.	SW.	W.	NW.	Dir.	Years.	Miles.	
											Dir.										Dir.		
January	3	97	89	16	15	36	51	24	30	...	27	25	5	4	10	14	7	8	...	30	N 4 E	2	126
February	3	44	22	13	7	78	104	30	37	...	13	7	4	2	23	31	9	11	...	38	S 54 W	3	192.5
March	3	18	7	12	9	99	156	41	29	...	5	2	3	2	27	42	11	8	...	62	S 40 W	3	231.4
April	3	3	9	14	19	139	148	19	9	...	1	2	4	5	39	41	5	2	...	76	S 22 W	3	394.1
May	3	3	5	7	61	176	110	4	6	...	1	1	2	16	47	30	1	2	...	82	S 6 W	3	344.8
June	3	4	8	10	47	142	114	24	10	...	1	2	3	13	39	31	8	3	...	71	S 15 W	2	204.1
July	3	4	6	13	49	122	132	35	11	...	1	2	3	13	33	36	9	3	...	73	S 20 W	2	254.8
August	3	12	14	22	34	91	140	49	10	...	3	4	6	9	24	38	13	3	...	60	S 28 W	2	261.8
September	3	11	23	33	57	122	88	9	7	...	3	7	9	16	35	25	3	2	...	58	S 4 E	2	242.3
October	3	68	50	21	34	67	56	26	44	...	18	13	6	9	18	15	7	12	...	5	N 81 W	2	135.5
November	3	158	80	14	8	13	27	17	42	...	44	22	4	2	4	7	5	12	...	60	N 3 E	2	103
December	3	124	102	22	2	17	45	22	38	...	33	27	6	1	5	12	6	10	...	49	N 5 E	2	.....
Year	...	...	...	...	...	...	...	...	...	...	12.5	9.5	5	8	25	27	7	6	...	...	.....	...	.....

II.—Calcutta.

Years.	N.	NE.	E.	SE.	S.	SW.	W.	NW.	$\frac{E}{S}$	N.	NE.	E.	SE.	S.	SW.	W.	NW.	$\frac{E}{S}$	Direction.	Years.	Miles.
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
January	10 2003	293	356	159	651	517	984	1253	121	32	5	6	2	10	8	15	20	2	N 38 W	3	104.5
February	10 846	334	453	265	1215	775	1069	842	39	15	6	8	4	4	13	18	14	1	S 79 W	3	114.8
March	10 466	161	233	277	2479	1198	1006	615	30	7	2	4	4	39	13	16	8	1	S 33 W	4	133.1
April	10 116	102	280	677	3684	846	295	147	31	2	2	4	11	60	14	5	2	...	S 3 W	4	203.9
May	10 162	194	621	1144	3211	607	154	112	96	3	3	10	18	51	10	2	2	...	S 12 E	4	209.7
June	10 185	288	550	879	2841	840	369	159	141	3	5	9	14	45	13	6	3	2	S 5 E	4	198.3
July	10 110	240	713	1159	3056	812	253	61	77	2	4	11	18	47	12	4	1	2	S 12 E	4	157.5
August	10 137	340	974	1149	2470	735	342	96	121	2	8	15	17	39	12	5	4	2	S 18 E	4	138.9
September	10 840	524	1028	1049	1965	479	407	224	152	5	5	17	17	32	8	7	4	2	S 30 E	4	131.7
October	10 1292	440	582	509	1039	487	941	928	173	20	7	9	8	16	5	15	14	3	N 53 W	4	87.0
November	10 2499	521	936	126	155	283	736	1421	51	41	9	5	2	5	5	12	23	1	N 19 W	4	82.1
December	10 2380	399	173	58	299	262	846	1658	53	39	6	3	1	31	4	14	27	1	N 27 W	4	91.2
Year	...	...	...	...	...	...	...	...	...	14	5	8	10	31	11	10	10	1	.....	..	...

III.—Berhampore.

41.

	OBSERVED.										PER CENT.							RESULTANT.		MEAN DIURNAL MOVEMENT.				
	Years.	N.	NE.	E.	SE.	S.	SW.	W.	NW.	Calm.	N.	NE.	E.	SE.	S.	SW.	W.	NW.	Calm.	Per cent.	Direc- tion.	Years.	Miles.	
January	3	73	47	11	11	5	28	83	114	...	20	13	3	3	1	7	22	41	...	...	57	N 40 W	2	37.2
February	3	46	30	14	17	29	45	81	71	...	14	9	4	5	9	14	24	21	...	...	38	N 68 W	2	41.4
March	3	24	19	10	24	39	97	116	43	...	6	5	3	6	11	26	31	12	...	...	51	S 72 W	2	56.5
April	3	14	33	43	38	100	64	47	21	...	4	9	12	10	28	18	13	6	...	...	32	S 7 W	2	88.7
May	3	11	44	80	71	88	28	36	14	...	3	12	21	19	24	7	10	4	...	...	40	S 43 E	2	99.7
June	3	12	41	63	68	118	24	23	11	...	3	11	18	19	33	7	6	3	...	...	47	S 35 E	2	128.9
July	3	6	51	90	86	96	28	6	2	...	2	14	24	23	26	7	2	...	...	2	56	S 49 E	2	99.4
August	3	11	84	65	73	66	40	15	4	...	7	22	17	20	18	11	4	...	...	41	S 59 E	2	78.1	
September	3	24	77	71	84	58	20	4	5	...	3	21	20	23	16	5	1	...	...	6	49	S 76 E	2	75.6
October	3	50	68	39	39	29	34	49	37	...	13	18	11	11	8	9	13	10	...	...	13	N 19 E	2	47.7
November	3	106	21	16	18	8	25	59	108	...	29	6	4	5	2	7	16	30	...	...	56	N 34 W	2	29.0
December	3	121	32	10	2	2	17	57	131	...	32	9	3	0.5	0.5	5	15	35	...	...	71	N 30 W	2	28.1
Year	...	...	...	...	...	...	...	...	...	...	11	12	12	12	15	10	13	14	...	...	...	.....	...	...

Berhampore, 1 year—(calms recorded.)

January	...	42	21	4	1	6	5	17	20	8	34	17	3	1	5	4	14	16	6	50	N 14 W	...	...
February	...	16	11	6	3	3	15	27	11	24	14	9	5	3	3	13	23	9	21	29	N 61 W	...	...
March	...	10	5	1	3	6	23	34	16	26	8	4	1	2	5	19	27	13	21	44	W	...	...
April	...	8	8	14	10	11	25	14	13	17	1	6.5	12	8	9	21	12	11	14	16	S 47 W	...	...
May	...	2	14	42	27	17	15	5	1	7	1	6	34	22	19	12	4	1	6	51	S 52 W	...	...
June	...	1	8	34	33	23	14	...	...	...	1	12	28	19	12	12	...	...	...	61	S 51 E	...	...
July	...	3	42	12	15	30	16	...	...	...	2	34	10	12	24	13	...	...	...	37	S 65 E	...	...
August	...	7	63	10	5	6	10	8	1	6	14	51	8	4	5	8	6	1	11	45	N 49 E	...	...
September	...	17	60	5	5	6	3	...	3	21	14	50	4	4	5	2.5	...	2.5	18	59	N 42 E	...	...
October	...	26	47	3	...	...	7	6	8	27	21	38	2	...	...	6	5	6	23	53	N 18 E	...	...
November	...	17	5	3	...	...	9	26	18	39	14	4	2	...	2	4	22	15	33	39	N 56 W	...	...
December	...	27	10	2	...	2	5	19	29	29	22	8	2	1	2	8	15	23	23	49	N 34 W	...	...
Year	...	...	...	...	...	...	...	...	...	...	12	20	9	7	8	10	11	8	15	...	...	.....	...

TABLE I.—WIND DIRECTIONS AND VELOCITIES.—(Continued.)

## IV.—Dacca.

	OBSERVED.										PER CENT.						RESULTANT.		MEAN DIURNAL MOVEMENT.					
	Years.	N.	NE.	E.	SE.	S.	SW.	W.	NW.	Calm.	N.	NE.	E.	SE.	S.	SW.	W.	NW.	Calm.	Per cent.	Direc- tion.	Y ears.	Miles.	
January	3	59	39	10	12	34	17	63	100	34	16	11	3	3	9	5	17	17	27	9	40	N 45 W	3	46·2
February	3	32	20	11	21	53	59	73	62	8	10	6	3	6	16	17	22	22	18	2	37	S 80 W	3	60·2
March	3	12	16	18	36	97	101	49	38	2	3	4	5	10	26	28	13	10	1	1	48	S 32 W	3	92·8
April	3	26	17	26	57	146	50	13	24	...	7	5	7	16	40	14	4	4	7	...	...	S 5 E	3	149·2
May	3	10	22	38	113	135	36	9	5	1	3	6	10	31	37	10	2	2	1	...	...	S 24 E	3	167·6
June	3	1	8	19	143	136	42	7	3	...	...	2	5	45	43	12	2	1	1	...	...	S 18 E	3	228·6
July	3	...	...	20	166	159	20	2	3	...	...	...	5	40	38	15	1	1	1	...	...	S 23 E	3	213·7
August	3	1	7	11	96	174	55	11	8	...	...	...	11	33	30	12	2	2	3	...	...	S 6 E	3	159·0
September	3	3	12	38	114	104	40	7	9	18	1	3	7	14	15	9	2	2	3	5	64	S 23 E	3	129·0
October	3	32	30	26	50	54	34	6	69	62	9	8	7	6	4	6	7	19	17	17	3	N 1 W	3	62·2
November	3	76	67	18	22	13	21	23	63	51	21	19	5	3	4	4	7	7	18	14	36	N 21 W	3	37·4
December	3	77	45	7	12	13	16	44	103	51	21	12	2	3	4	4	12	28	28	14	47	N 28 W	3	42·7
Year	...	...	...	...	...	...	...	...	...	...	8	7	6	19	26	11	7	7	11	5	...	.....	...	...

## ASSAM.

## I.—Goalpara.

January	3	10	36	159	27	13	30	65	16	...	3	10	45	8	4	18	4	...	...	30	S 86 E	3	90·2
February	3	12	43	138	30	9	34	58	12	...	3·5	13	41	10	3	17	3	...	...	30	S 88 E	3	129·0
March	3	14	47	129	13	8	22	67	10	...	5	15	42	7	2	22	2	...	...	27	N 75 E	3	167·9
April	3	8	34	156	22	9	20	36	15	...	3	11	52	7	3	12	3	...	...	45	N 88 E	3	196·2
May	3	10	29	221	31	21	18	25	17	...	3	8	59	8	6	7	3	...	...	58	S 86 E	3	173·0
June	3	18	34	132	25	33	37	55	28	...	5	9	37	7	9	15	6	...	...	21	S 78 E	3	127·1
July	3	11	20	115	29	55	46	74	20	...	3	6	31	8	15	20	5	...	...	20	S 28 E	3	91·7
August	3	13	22	107	40	57	48	60	23	...	4	6	29	11	15	13	6	...	...	23	S 29 E	3	106·1
September	3	18	32	130	30	34	40	50	23	...	5	9	36	8	10	14	7	...	...	23	S 71 E	3	126·7
October	3	5	34	174	40	33	31	41	14	...	1	9	47	11	11	11	4	...	...	43	S 74 E	3	97·7
November	3	8	35	190	25	17	21	34	14	...	2	10	52	7	5	9	6	...	5	63	S 88 E	3	102·1
December	3	14	42	191	51	13	21	24	10	...	4	11	52	14	3	7	9	...	3	58	S 86 E	3	84·2
Year	...	...	...	...	...	...	...	...	...	...	3	10	44	8	7	14	7	...	...	.....	...	...	

II.—Seesaugor.

OBSERVED.										PER CENT.							RESULTANT.		MEAN DIURNAL MOVEMENT.			
Years.	N.	NE.	E.	SE.	S.	SW.	W.	NW.	E. $\frac{1}{2}$ $\frac{1}{2}$	N.	NE.	E.	SE.	S.	SW.	W.	NW.	E. $\frac{1}{2}$ $\frac{1}{2}$	Per cent.	Direction.	Years.	Miles.
3	122	110	91	...	12	6	31	...	...	33	30	24	...	3	2	8	...	...	61	N 36 E	...	...
3	125	27	69	...	8	16	29	...	...	45	10	25	...	3	6	11	...	...	40	N 33 E	...	...
3	126	103	48	...	13	54	18	...	...	35	28	13	...	4	15	5	...	...	44	N 27 E	...	...
3	116	94	55	...	17	67	11	...	...	32	26	15	...	5	19	3	...	...	37	N 28 E	...	...
3	138	88	13	...	13	104	16	...	...	37	24	35	...	35	28	4	...	...	45	N 8 W	...	...
3	99	63	4	...	36	150	18	...	...	27	15	1	...	10	42	5	...	...	23	S 85 W	...	...
3	37	27	1	...	88	179	40	...	...	10	7	...	...	24	43	11	...	...	58	S 43 W	...	...
3	35	21	5	...	106	167	38	...	...	9	6	1	...	29	45	10	...	...	59	S 38 W	...	...
3	68	95	5	...	51	110	31	...	...	19	26	1	...	14	31	9	...	...	10	N 80 W	...	...
3	124	145	33	...	35	21	14	...	...	33	39	9	...	9	6	4	...	...	56	N 31 E	...	...
3	131	160	55	...	12	2	...	...	...	36	45	15	...	3	1	...	...	...	80	N 36 E	...	...
3	122	180	62	...	4	4	...	...	...	33	48	17	...	1	1	...	...	...	82	N 38 E	...	...
...	...	...	...	...	...	...	...	...	...	29	25	11	...	9	20	6	...	...	...	.....	...	...
January	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
February	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
March	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
April	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
May	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
June	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
July	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
August	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
September	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
October	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
November	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
December	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Year	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...

ARAKAN COAST.

I.—Chittagong.

Years.	N.	NE.	E.	SE.	S.	SW.	W.	NW.	E. $\frac{1}{2}$ $\frac{1}{2}$	N.	NE.	E.	SE.	S.	SW.	W.	NW.	E. $\frac{1}{2}$ $\frac{1}{2}$	Per cent.	Direction.	Years.	Miles.	
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
January	159	76	49	8	4	29	92	70	...	33	15	10	1	1	6	20	14	...	194	N 34 W	3	1344	
February	81	53	50	17	36	62	79	65	...	18	12	11	4	8	14	18	15	...	226	N 43 W	3	1318	
March	70	49	28	23	64	116	95	47	...	14	10	6	5	13	24	19	9	...	310	S 79 W	3	1436	
April	33	27	40	51	120	122	63	21	...	7	6	8	11	25	26	13	4	...	395	S 21 W	3	1894	
May	25	23	60	78	105	131	56	15	...	5	6	6	12	21	27	11	3	...	409	S 6 W	3	1889	
June	11	19	96	157	120	57	15	3	...	1	2	4	33	25	12	3	1	...	614	S 33 E	3	1997	
July	1	13	131	167	125	42	8	...	...	6	3	27	34	25	8	2	...	...	696	S 40 E	3	1952	
August	3	8	118	141	128	80	27	4	...	7	1	22	26	24	15	5	...	1	541	S 31 E	3	1607	
September	15	41	121	110	96	94	26	11	...	24	8	23	20	18	17	16	9	...	423	S 34 E	3	1328	
October	3	67	82	58	41	61	91	51	...	20	12	15	10	7	13	15	4	...	69	N 21 E	3	1026	
November	3	118	135	58	18	9	34	83	...	15	22	11	3	2	6	15	13	...	402	N 2 E	3	1062	
December	201	63	43	8	9	34	99	96	...	3	11	8	1	2	6	18	17	1	...	524	N 19 W	3	1202
Year	...	...	...	...	...	...	...	...	...	...	10	145	14	14	145	12	7	1	...	...	...	...	...

TABLE I.—WIND DIRECTIONS AND VELOCITIES.—(Concluded.)

II.—Akycab.

		OBSERVED.										PER CENT.								RESULTANT.		
		Years.	N.	NE.	E.	SE.	S.	SW.	W.	NW.	Calm.	N.	NE.	E.	SE.	S.	SW.	W.	NW.	Calm.	Per cent.	Direc- tion.
January	...	3	45	92	26	21	12	17	71	78	6	12	25	7	6	3	4	19	23	1	44.7	N 14 W
February	...	3	40	94	25	4	2	8	43	113	19	11	27	7	1	1	2	12	33	6	51.5	N 11 W
March	...	3	39	81	48	24	7	16	75	145	46	8	17	10	5	1	3	16	30	10	36.7	N 22 W
April	...	3	29	36	34	28	29	54	86	100	6	7	9	9	7	7	13	21	25	2	30.3	N 72 W
May	...	3	19	27	42	55	49	89	63	63	22	4	6	10	13	11	21	15	15	5	22.8	S 46 W
June	...	3	6	15	33	74	96	1.6	10	22	16	1	4	8	19	24	32	2	6	4	61.7	S 5 W
July	...	3	1	6	40	166	169	97	6	7	2	0	1	8	33	34	20	1	2	2	71.7	S 13 E
August	...	3	11	13	48	119	119	138	26	16	4	2	3	10	24	24	15	6	3	1	64.5	S 1 E
September	...	3	17	28	69	1.5	140	78	37	31	8	3	5	14	21	27	15	7	6	2	42.2	S 13 E
October	...	3	24	78	7	62	62	71	63	49	17	5	15	17	12	12	14	13	9	3	10.4	S 38 E
November	...	3	88	110	37	37	14	42	84	91	3	17	22	7	7	3	8	17	18	1	32.5	N 13 W
December	...	3	91	142	24	19	2	23	81	82	88	17	26	4	3	0	4	15	15	16	30.4	N 6 W
Year	...	...	...	...	...	...	...	...	...	...	...	7	13	9	13	12	14	12	16	4	...	.....

TABLE II.—MONTHLY MEANS OF OBSERVED TEMPERATURES.

	Eleva- tion in feet.	Years.	Jan.	Feb.	March.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Method of reduction.
Rawulpindeo	1,700?	3	50.9	54.9	60.4	71.9	85.6	92.1	89.5	86.	84.1	72.8	61.2	52.7	Mean of max. and min. corr. by Roorkee.
Mooltan	400?	7	52.9	59.4	68.8	80.3	89.9	92.	92.6	89.5	85.7	75.	64.6	55.5	ditto.
Lahore	700?	3	53.5	58.6	66.3	79.7	90.6	93.4	89.5	88.	85.6	78.1	65.7	56.7	ditto.
Roorkee	880	5	57.6	62.3	69.6	81.4	83.8	89.	84.5	84.2	83.	76.	63.7	57.5	4h, 10h, 16h, 22h.
Agra	550	4	58.7	63.9	73.3	84.1	93.6	92.9	87.5	84.7	83.9	79.1	69.3	61.8	min. and 16h.
Benares	263	3-5	58.5	67.8	75.2	86.2	91.2	90.2	85.9	85.2	84.	79.2	68.5	59.1	4h, 10h, 16h, 22h(part min. and 16h.)
Patna	179	4	60.7	66.2	76.6	83.7	87.	87.2	84.1	83.4	82.3	78.9	68.9	61.8	ditto.
Ajmere	1,800	4	58.3	65.	72.9	84.4	92.4	91.5	86.	83.3	84.9	79.1	70.3	63.8	min. and 16h.
Jhansi	900	4	60.8	68.3	75.4	85.6	95.1	90.9	83.6	82.3	82.	77.9	69.6	63.	ditto.
Jubbulpore	1,353	3	62.9	67.2	73.5	84.2	90.2	87.4	78.6	77.9	78.7	75.	67.6	62.7	ditto.
Nagpore	1,025	3	70.5	75.1	81.1	87.3	93.8	86.	78.4	78.9	79.	77.5	72.3	68.7	ditto.
Hoshungabad	1,030	2-3	65.9	72.1	77.5	88.5	93.4	95.2	79.2	78.9	79.8	78.7	73.1	69.8	ditto.
Bombay	20	18	73.7	75.8	77.4	83.	85.5	83.2	81.3	80.4	80.3	81.6	79.4	76.	hourly observations.
Monghyr	160	4	62.8	68.5	77.1	84.7	86.8	86.2	84.1	83.8	82.8	80.4	71.4	63.5	4h, 10h, 16h, 22h.
Hazareebagh	2,014	4	61.7	66.2	74.3	82.6	85.9	81.4	79.2	77.9	77.3	74.5	68.9	61.6	ditto.
Cuttack	80	4	70.2	74.4	80.1	86.	89.	85.8	84.	84.	83.2	81.5	74.6	69.6	ditto.
False Point	19	4	71.2	75.2	80.1	84.	87.1	86.3	85.3	85.1	85.2	84.1	77.4	70.9	ditto.
Saugor Island	6	4	69.	74.	79.9	83.9	85.6	85.1	84.1	83.5	83.1	81.2	75.	68.2	ditto.
Calcutta	18	16	68.8	73.3	79.6	83.6	85.	83.7	83.1	83.2	82.6	81.7	75.1	68.5	hourly observations.
Berhampore	65	4	65.3	70.7	78.2	85.5	86.3	84.6	81.	84.1	83.4	81.7	73.5	66.2	4h, 10h, 16h, 22h.
Dacca	20	4	67.5	72.8	79.8	83.	83.6	83.5	83.2	83.8	83.2	81.6	74.9	68.5	ditto.
Cachar	89	2-3	61.4	68.2	74.5	78.2	81.1	81.9	82.1	81.6	81.5	80.5	74.2	67.9	ditto.
Chittagong	90	4	67.6	71.7	77.9	81.2	83.	81.6	80.9	81.3	81.5	80.5	74.2	72.	ditto.
Akyab	21	2-4	70.5	74.6	78.9	83.6	81.4	82.3	81.	81.6	82.	81.5	77.8	72.	ditto.
Darjeeling	6,941	4	42.9	44.5	50.4	56.1	60.2	63.3	63.9	64.	62.1	58.	50.2	44.	4h, 10h, 16h, 22h.
Goalpara	386	3	64.3	67.4	73.	77.1	78.2	79.9	81.	81.3	80.	78.3	66.	50.1	ditto.
Shillong	4,792	3	51.3	51.2	61.4	64.5	68.4	69.4	69.4	69.2	67.3	63.5	56.	50.1	ditto.
Sebsaugor	500?	3	58.6	62.6	66.8	73.4	80.	83.8	84.8	84.6	83.2	79.8	69.9	61.3	sunrise 10h, 16h, 22h.
Chuckrata	6,884	2-3	42.6	44.5	50.2	59.5	68.7	69.5	65.7	65.1	62.2	59.2	53.5	44.2	4h, 10h, 16h, 22h.

TABLE III.—MEAN TEMPERATURES AT SEA LEVEL  
(Reduced from Table II.)

	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
Rawulpindee ...	55.7	59.7	65.2	76.7	90.2	96.9	94.3	90.8	88.9	77.6	66	57.5
Mooltan ...	54	60.5	69.9	81.4	91	95.1	93.7	90.6	86.8	76.1	65.7	56.6
Lahore ...	56.5	60.6	68.3	81.1	92.6	95.4	91.5	90	87.6	80.1	67.7	57.7
Roorkee ...	60.1	64.8	72.1	82.9	91.3	91.5	87	86.7	85.5	78.5	66.2	60
Agra ...	60.2	65.4	74.8	85.6	95.1	94.4	89	86.2	85.4	80.6	70.8	63.3
Benares ...	59.2	66.5	75.9	86.9	91.9	90.9	86.6	85.9	84.7	79.9	69.2	59.8
Patna ...	61.2	66.7	77.1	84.2	87.5	87.7	84.6	83.9	82.8	79.4	69.4	62.3
Ajmere ...	63.4	70.1	78	89.5	97.5	96.6	91.1	88.4	90	84.2	75.4	68.9
Jhansi ...	63.4	70.9	78	88.2	97.3	93.5	86.2	84.9	84.6	80.5	72.2	65.6
Jubbulpore ...	66.8	71.1	77.4	88.1	94.1	91.3	82.5	81.8	82.6	78.9	71.5	66.6
Nagpore ...	73.4	78	84	90.2	96.7	88.9	81.3	81.9	81.9	80.4	75.2	71.6
Hoshungabad ...	68.9	75.1	80.5	91.5	96.4	98.2	82.2	81.9	82.8	81.7	76.1	73.8
Bombay ...	73.7	75.8	77.4	88	85.5	83.2	81.3	80.4	80.3	81.6	79.4	76
Monghyr ...	63.2	68.9	77.5	85.1	87.2	86.6	84.5	83.6	83.2	80.8	71.8	63.9
Hazareebagh ...	67.4	71.9	80	88.3	91.6	87.1	84.9	83.6	83	80.2	74.6	67.3
Cuttack ...	70.4	74.6	80.3	86.2	89.2	86	84.2	84.2	83.4	81.7	74.8	69.8
False Point ...	71.2	75.2	80.1	84	87.1	86.3	85.3	85.1	85.2	84.1	77.4	70.9
Saugor Island ...	69	74	79.9	83.9	85.6	85.1	84.1	83.5	83.1	81.2	75	68.2
Calcutta ...	67.6	72.8	80.5	84.5	86	84.9	83.5	83	83.2	81.4	74.7	67.8
Berhampore ...	65.5	70.8	78.4	85.7	86.5	84.8	84.2	84.3	83.6	81.9	73.7	66.4
Pacca ...	67.5	72.8	79.8	82	83.6	83.5	83.2	83.8	83.2	81.6	74.9	68.5
Chittagong ...	64.7	69.6	74	78.9	82.1	81.9	82.3	81.8	81.6	80	72.3	65.2
Goalpara ...	67.9	71.9	78.2	81.5	83.3	81.9	81.2	81.6	81.8	80.8	74.5	68.2
Seesaugor ...	65.4	68.5	74.1	78.2	79.3	81	82.1	82.4	81.1	79.4	72.2	65.9
	60	64	68.2	74.8	81.4	85.2	86.2	8.	84.6	81.2	71.3	62.7

TABLE IV.—MONTHLY MEAN VAPOUR TENSIONS.

	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
Rawulpindee	0.227	0.271	0.304	0.406	0.392	0.511	0.651	0.658	0.537	0.370	0.324	0.231
Mooltan	0.208	0.248	0.330	0.371	0.263	0.479	0.611	0.638	0.514	0.373	0.292	0.237
Lahore	0.283	0.310	0.406	0.448	0.488	0.579	0.777	0.754	0.686	0.430	0.341	0.280
Roorkee	0.299	0.365	0.390	0.404	0.488	0.737	0.911	0.891	0.823	0.637	0.336	0.293
Benares	0.339	0.373	0.393	0.475	0.585	0.864	0.977	0.943	0.943	0.657	0.498	0.325
Patna	0.328	0.347	0.402	0.444	0.659	0.881	0.969	0.948	0.914	0.729	0.466	0.342
Jubbulpore	0.326	0.359	0.412	0.398	0.439	0.714	0.654	0.687	0.725	0.633	0.466	0.341
Bombay	0.447	0.478	0.583	0.514	0.539	0.769	0.776	0.749	0.752	0.631	0.594	0.462
Nagpore	0.586	0.631	0.727	0.825	0.890	0.933	0.921	0.884	0.869	0.865	0.709	0.623
Hazareebagh	0.280	0.264	0.330	0.423	0.557	0.796	0.867	0.812	0.786	0.563	0.360	0.279
Cuttack	0.509	0.569	0.676	0.831	0.941	0.949	0.954	0.954	0.941	0.817	0.581	0.484
False Point	0.608	0.698	0.831	0.978	1.079	1.040	1.020	1.013	0.972	0.911	0.647	0.551
Saugor Island	0.531	0.662	0.813	0.939	1.005	1.025	1.016	1.008	0.995	0.893	0.659	0.523
Calcutta	0.437	0.548	0.695	0.805	0.893	0.947	0.954	0.950	0.950	0.828	0.613	0.489
Berhampore	0.417	0.442	0.511	0.769	0.877	0.985	1.001	0.993	0.970	0.832	0.585	0.450
Dacca	0.437	0.483	0.660	0.774	0.908	0.974	0.976	0.995	0.965	0.851	0.596	0.459
Cachar	0.479	0.538	0.637	0.749	0.913	0.950	0.974	0.969	0.952	0.874	0.652	0.500
Chittagong	0.479	0.566	0.715	0.861	0.924	0.937	0.926	0.949	0.934	0.863	0.650	0.497
Akyab	0.581	0.650	0.739	0.885	0.955	0.947	0.929	0.926	0.938	0.902	0.761	0.604
Darjeeling	0.212	0.238	0.262	0.388	0.427	0.529	0.546	0.543	0.501	0.381	0.276	0.213
Gaolpara	0.439	0.435	0.487	0.632	0.790	0.897	0.919	0.916	0.900	0.782	0.593	0.459
Shillong	0.265	0.273	0.321	0.394	0.534	0.598	0.629	0.627	0.588	0.503	0.341	0.271

N.B.—The values for Calcutta and Bombay are obtained from hourly observations with the Psychrometer each observation being reduced separately, and are therefore as accurate as are obtainable with that instrument. The remainder are computed directly from the figures in Tables II and V, and represent only a rough approximation to the real values, which will be somewhat higher.

TABLE V.—MONTHLY MEAN HUMIDITY  
(Saturation=100.)

	Years.	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
Rawalpindce	5	61	63	53	52	32	34	47	53	46	46	60	58
Mooltan	5	52	49	47	36	28	30	40	46	41	43	43	54
Lahore	5	69	63	63	46	34	37	56	57	56	46	54	63
Roorkce	4	63	65	54	39	36	54	77	76	73	60	57	62
Benares	4-5	69	65	45	38	40	61	79	80	81	66	63	65
Patna	3-4	62	54	44	42	53	66	83	83	83	74	66	62
Jubulpore	3	57	54	50	34	31	55	67	72	74	73	69	60
Nagpore	3	60	55	55	39	34	62	80	76	79	67	75	66
Bombay	18	70	72	77	73	73	82	86	85	84	79	70	69
Hazareebagh	3-4	51	41	39	33	45	72	87	85	84	66	51	51
Cuttack	4	69	67	65	67	69	77	82	82	83	77	68	67
False Point	4	79	80	81	84	84	83	84	84	82	78	69	73
Saugor Island	3-4	75	79	80	81	82	85	87	88	88	84	76	76
Calcutta	16	71	68	67	69	73	81	85	86	85	78	73	72
Berhampore	3-4	67	59	53	63	70	83	86	85	85	77	71	70
Dacca	4	65	60	65	71	79	85	86	86	85	79	69	66
Cachar	2-3	79	75	74	76	81	88	89	90	89	86	83	81
Chittagong	3-4	71	73	75	81	82	87	88	89	87	83	77	73
Akyab	3-4	78	76	75	77	81	86	88	86	86	84	80	77
Darjeeling	4	77	81	69	75	82	91	92	92	90	79	76	74
Goalpara	3	73	65	60	68	68	82	87	86	88	83	78	75
Shillong	3	70	65	59	65	77	84	87	88	88	86	76	75
Chuckrata	3-4	51	55	60	42	44	67	90	92	86	58	44	50

N.B.—The mean humidities of the three Punjab stations are obtained from observations of the Psychrometer at 10 A.M. and 4 P.M. multiplied by factors deduced from the Roorkce registers. Those of Nagpore and Jubulpore from similar data, multiplied by factors deduced from the Benares registers. Those of Bombay and Calcutta are the means of hourly observations, and all others are the means of observations recorded daily at 4h., 10h., 18h., and 22h.

TABLE VI.—AVERAGE MONTHLY AND ANNUAL RAINFALL IN NORTHERN INDIA, &c.

*Arakan, Eastern Bengal, and Assam.*

	Years.	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
I.—Sandoway	3-5	0.14	.....	0.24	1.35	14.01	55.32	64.50	51.36	30.91	17.09	1.15	...	238.07
II.—Akyab	12-14	0.35	0.28	0.53	1.30	10.50	50.91	53.81	36.93	25.67	13.45	5.91	.25	199.89
III.—Chittagong	13-15	0.39	1.30	1.39	5.08	8.76	22.68	21.95	22.50	12.99	7.17	1.93	.46	106.50
IV.—Noakhally	13-15	.36	.72	1.75	4.05	9.09	21.92	17.09	20.12	15.77	8.71	1.54	.08	101.15
V.—Tipperah	11-12	.64	.89	2.29	8.34	11.92	20.34	16.81	13.98	10.69	6.76	1.77	.04	94.47
VI.—Cachar	11-13	.42	3.26	5.67	12.09	15.01	19.01	23.71	16.79	14.03	7.88	.88	.66	119.41
VII.—Silhet	12-15	.13	1.45	4.56	13.93	23.68	30.42	25.56	26.23	4.99	9.87	.71	.14	141.67
VIII.—Cherra Punji	5-12	.52	3.34	8.34	34.67	64.34	115.19	150.38	75.93	58.23	18.05	2.58	...	527.26
IX.—Shillong	5-6	.14	.59	1.51	3.66	9.31	17.57	13.63	9.84	17.29	6.07	1.63	.16	81.45
X.—Sebsaugor	12-14	1.21	2.39	3.85	9.78	11.20	15.41	16.36	15.48	11.17	4.64	1.47	.65	93.61
XI.—Nazeerah	9-10	1.51	2.33	2.83	9.18	7.77	14.22	13.56	15.75	10.27	4.67	.72	.75	83.66
XII.—Tezapore	10-12	.56	1.00	1.10	7.17	10.28	14.90	15.41	13.26	8.64	3.10	.94	.75	77.11
XIII.—Nowgong	10-12	1.14	1.29	2.52	6.04	10.97	12.58	15.43	15.44	12.28	4.64	.61	.31	83.25
XIV.—Gowhaty	10-12	.56	1.37	1.43	7.04	10.52	13.73	12.06	11.10	7.87	3.05	.38	.11	69.23
XV.—Goalpara	7-8	.31	.64	1.83	5.15	13.09	25.70	21.19	12.46	11.46	5.43	.37	.15	97.78

*Gangetic Delta and Northern Bengal.*

XVI.—Mymensing	7-8	.26	1.27	1.37	8.33	14.26	24.13	20.77	14.99	13.62	5.97	.13	...	105.10
XVII.—Dacca	11-12	.62	.76	1.46	7.00	9.94	14.12	13.15	12.43	8.89	5.97	.89	.06	75.29
XVIII.—Bogra	8-11	.32	.90	1.00	5.05	9.33	17.62	20.25	12.72	15.71	5.90	1.50	.09	90.39
XIX.—Rangpore	10-12	.13	.28	1.00	2.78	10.01	24.33	19.07	13.53	12.07	4.71	.36	.13	83.45
XX.—Dinajpore	10-12	.13	.66	.87	2.90	8.64	20.50	17.47	14.19	14.02	5.94	.21	.02	85.54
XXI.—Maldah	14-16	.80	1.52	1.63	1.93	3.42	8.80	10.19	9.73	10.67	4.60	.24	.51	54.04
XXII.—Rampore Beauléah	10-12	.13	1.14	1.41	2.25	5.79	11.76	13.36	9.93	10.63	5.39	.34	.06	62.19
XXIII.—Berhampore	14-16	.33	.81	1.15	2.37	4.22	9.65	10.53	9.87	9.31	5.75	.21	.10	54.30
XXIV.—Jessore	10-14	.24	.41	1.96	3.94	7.33	13.52	11.09	11.09	9.25	6.36	.86	.01	66.06
XXV.—Kishnagar	8-12	.52	.82	.90	4.51	7.71	11.57	9.56	9.78	7.61	4.90	.35	.18	58.41
XXVI.—Burdwan	12-15	.67	1.03	1.47	2.02	4.20	10.67	12.93	11.98	8.98	5.46	.51	.49	60.31
XXVII.—Calcutta	32	.53	.72	1.22	2.25	5.43	11.40	13.33	14.18	10.36	5.31	.67	.24	66.04
XXVIII.—Sangor Island...	4-5	.05	.82	1.73	2.26	5.77	15.09	15.21	16.85	17.43	11.46	.94	...	87.61

TABLE VI.—AVERAGE MONTHLY AND ANNUAL RAINFALL IN NORTHERN INDIA.—(Continued.)

*Orissa and Plateau of Western Bengal.*

	Years.	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
XXIX.—Pooree	14-15	.09	1.37	.71	1.81	2.37	7.79	9.29	12.01	9.58	7.26	1.22	.79	54.29
XXX.—False Point	6	.02	.77	1.77	2.72	2.70	14.08	13.67	11.22	11.92	12.06	3.97	...	74.45
XXXI.—Cuttack	11-14	.49	.48	1.09	1.74	1.63	9.24	11.09	10.63	9.03	5.48	.97	.65	52.52
XXXII.—Balasore	10-12	1.09	1.15	1.97	3.15	4.50	12.08	9.06	12.12	13.74	7.25	.89	...	67.00
XXXIII.—Midnapore	6-8	.89	.39	2.20	1.72	5.99	14.02	11.62	11.41	9.79	6.27	.43	...	64.77
XXXIV.—Bancoorah	14-16	.40	.86	1.49	1.97	3.09	10.09	12.44	10.17	8.13	4.18	.19	.08	53.09
XXXV.—Raneegunj	5	.22	.39	1.25	1.05	2.73	10.70	14.56	11.98	9.83	3.81	.14	...	65.36
XXXVI.—Soory	9	.47	.53	.80	.81	2.39	8.81	12.41	12.15	8.97	3.64	.05	.18	51.46
XXXVII.—Purulia	7-10	.31	.55	.79	.78	1.13	9.22	8.75	11.17	6.64	4.59	.13	.23	44.21
XXXVIII.—Hazareebagh	6-7	.30	.41	.80	.46	1.38	9.61	14.68	13.16	8.35	3.54	.13	.08	52.91
XXXIX.—Ranchee	14-16	.94	.91	1.63	.56	1.47	6.52	10.37	9.76	6.65	3.22	.12	.10	42.25

*Gangetic Plains (Behar and North-Western Provinces.)*

XL.—Bhagulpore	15-16	.50	.74	.44	1.02	2.10	8.44	11.00	10.72	8.98	4.97	.03	.08	48.92
XLI.—Monghyr	15-16	.37	.61	.54	.41	.61	6.21	10.82	8.16	7.73	3.78	.05	.11	40.43
XLII.—Gya	8-10	.87	.50	.63	.58	.94	7.01	12.51	9.18	7.35	3.44	.05	.08	48.14
XLIII.—Patna	9-10	.49	.79	.27	.49	1.12	6.78	10.61	7.44	6.35	2.66	.10	.06	37.16
XLIV.—Arrah	13-16	.88	.54	.65	.89	1.35	7.64	13.90	10.77	10.53	3.05	.24	.07	50.51
XLV.—Chuprah	13-16	.68	.50	.47	.56	1.29	6.76	9.14	8.45	7.14	2.87	.02	...	37.83
XLVI.—Mozufferpore	11-13	.59	.51	.58	.46	1.89	6.85	10.54	9.98	8.66	3.70	.03	...	43.79
XLVII.—Chumparun	8-10	.24	.31	.90	.35	1.80	8.04	10.61	11.37	7.66	3.66	...	.11	45.05
XLVIII.—Benares	8-9	.74	.42	.33	.17	.57	4.24	12.43	5.99	7.69	2.13	.02	...	34.03
XLIX.—Goruckpore	5	.72	.48	.39	.26	.98	8.19	15.12	9.74	7.60	5.64	...	.04	49.25
L.—Lucknow	5	1.56	.06	.39	.30	.62	4.34	16.55	7.85	9.95	2.55	...	.29	44.45
LI.—Agra...	8-9	.48	.29	.57	.17	.30	2.81	10.02	7.76	3.17	.60	...	.20	25.30
LII.—Delhi	6	.87	.40	1.57	.63	.76	6.85	13.61	8.44	1.93	.28	...	.58	22.64
LIII.—Bareilly	4-5	.92	1.41	1.00	.46	.29	5.55	9.91	9.86	8.64	1.47	...	.35	42.14
LIV.—Roorkee	8	1.62	2.39	1.59	.54	.74	4.06	9.91	9.86	4.30	.75	.34	.78	36.88
LV.—Umbala	6	1.27	2.97	1.42	1.49	1.00	4.05	9.30	6.62	3.10	.23	...	.10	31.55

*Rajpootana, Bundelkand, and Nerbudda Valley.*

LVI.—Nimar	...	5	0.12	.....	0.07	0.04	.24	9.39	13.75	9.04	6.18	.96	.02	.07	39.88
LVII.—Hoshungabad	...	10	.35	.21	.20	.05	.60	4.50	15.19	13.89	9.31	.77	.71	.28	46.06
LVIII.—Nursingpore...	...	10	.03	.16	.21	.15	.52	6.80	14.08	10.93	7.58	1.19	.25	.28	42.18
LIX.—Jubbulpore	...	10	.54	.54	.57	.09	.08	8.96	18.96	12.45	7.86	1.35	.13	.26	51.79
LX.—Saugar	...	14	.27	.78	.30	.11	.50	9.20	15.54	12.32	8.24	1.12	.32	.86	49.56
LXI.—Jhansi	...	4.7	2.04	.24	.47	.02	.25	4.60	14.13	6.17	4.12	1.77	...	.38	34.19
LXII.—Ajmere	...	6.7	1.35	.21	.48	.26	.19	1.13	5.74	9.50	2.82	.19	...	.39	22.26

*Central India (South of Satpooras).*

LXIII.—Wardha	...	5	.98	.....	.28	.46	.30	5.72	10.31	11.32	6.58	1.72	.12	.07	37.86
LXIV.—Nagpore	...	13	1.01	.49	.94	.44	.50	8.73	11.33	9.50	8.32	2.75	.60	.11	44.72
LXV.—Chindwara	...	5	1.03	.....	1.33	.18	.35	8.98	10.64	8.86	6.68	2.37	...	.17	40.59
LXVI.—Seoni	...	9	.45	1.02	.72	.49	.48	8.14	14.93	10.65	6.26	1.73	.41	.61	45.89
LXVII.—Chanda	...	5	.05	.21	1.81	.37	.31	8.16	15.96	11.18	8.86	2.45	.30	.16	49.82
LXVIII.—Raipore	...	5	.91	.....	1.39	.70	.22	11.41	14.66	11.94	8.42	4.77	2.74	...	57.16
LXIX.—Belaspore	...	5	.95	.17	1.56	.87	.33	9.72	10.87	10.46	4.59	1.93	.29	.18	41.92
LXX.—Sumbulpore...	...	7.10	.56	.61	.59	.28	1.04	10.04	13.05	10.63	7.44	4.38	.06	.12	48.80

*Western India (South of Satpooras).*

LXXI.—Bombay	...	23	.05	.01	.....	.05	.56	20.84	24.26	13.16	9.64	2.20	.47	.05	71.30
LXXII.—Mahableshwar	...	15	.05	.25	.15	1.31	3.31	46.53	92.10	72.33	31.32	4.58	2.07	.05	254.05
LXXIII.—Poonah	...	7	.32	.....	.14	.25	1.36	5.65	6.50	3.13	4.34	4.70	.68	.23	27.30
LXXIV.—Sattara	...	4	.14	.04	.04	2.90	1.71	5.46	13.29	8.06	3.38	4.11	2.40	.62	42.15
LXXV.—Sholapore	...	10	.11	.06	.25	1.26	1.78	4.95	3.26	4.57	6.65	3.64	1.25	.12	27.90

*Punjab.*

LXXVI.—Lahore	...	5.6	.75	1.06	1.16	.57	1.16	.99	4.20	1.18	1.34	.72	...	.44	13.57
LXXVII.—Shahpoor	...	5	.08	.88	.86	.32	.38	1.46	1.70	2.60	.58	.02	...	.44	9.32
LXXVIII.—Rawalpindie	...	5.5	1.57	2.72	2.89	1.85	.87	2.49	6.66	5.40	2.66	.94	...	.94	28.29
LXXIX.—Feshawar	...	5	.64	1.36	1.30	1.80	.24	.28	.72	1.52	1.76	.32	...	.96	10.90
LXXX.—Dera Ishmail	...	5	.20	.64	1.44	.50	.10	1.48	1.04	.85	.44	.02	...	.40	7.11
LXXXI.—Mooltan	...	9	.42	.35	.78	.95	.39	.31	1.62	1.13	.55	.29	.03	.37	7.19
LXXXII.—Hissar	...	6	.34	.62	.61	.24	.18	2.68	4.56	2.68	1.16	...	...	.38	13.45
LXXXIII.—Sirsa	...	6	.23	.52	.74	.26	.34	3.07	3.90	2.12	1.57	...	...	.30	13.05

*Himalaya.*

	Years.	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
LXXXIV.—Buxa Fort	3	.37	1.23	1.63	8.03	27.37	47.37	81.02	57.01	36.10	17.73	.91	.85	280.22
LXXXV.—Rungbee	6	.94	1.61	2.56	6.36	10.15	31.73	51.41	34.56	26.82	8.44	.49	.23	175.25
LXXXVI.—Darjeeling	9-12	.61	1.48	1.74	3.95	7.22	28.41	29.76	27.57	17.93	7.92	.26	.11	126.96
LXXXVII.—Khatmandu	4	0.44	1.79	0.17	2.61	3.11	7.25	12.06	11.86	6.27	4.96	0.47	1.21	52.09
LXXXVIII.—Naini Tal	7-8	6.39	4.09	4.47	2.08	2.82	13.20	19.26	20.18	7.88	3.51	.09	2.61	86.58
LXXXIX.—Dehra	5	1.58	2.33	2.90	.66	.65	6.44	26.70	20.03	9.83	.81	...	.38	72.29
XG.—Simla	6	1.40	.80	3.83	2.35	2.87	9.93	17.72	13.89	4.66	.33	...	.42	58.20
XCI.—Kangra	5-6	3.13	6.13	4.78	1.31	1.78	11.80	38.30	28.04	8.94	.48	.32	1.07	106.08
XCII.—Hazara	5	2.22	4.90	6.54	2.68	2.10	5.14	8.06	5.90	2.98	1.08	...	2.04	43.64

TABLE VII.—MONTHLY MEANS OF OBSERVED ATMOSPHERIC PRESSURES DEDUCED FROM  
THE REGISTERS OF THE 5 YEARS 1867-71.

	Year.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
Simla	3	23-225	23-198	23-197	23-207	23-142	23-061	23-069	23-101	23-194	23-227	23-293	23-254	23-135
Roorkee	6	29-125	29-048	28-985	28-878	28-747	28-632	28-638	28-695	28-792	28-960	29-104	29-154	28-896
Agra	4	5-09	4-37	29-358	29-243	29-098	29-098	29-166	29-035	29-133	29-321	29-477	29-522	29-250
Lucknow	3	6-94	6-08	5-27	4-03	2-76	29-161	29-166	2-33	3-26	4-99	6-56	7-11	4-39
Benares	5	8-13	7-27	6-44	5-28	3-88	2-73	2-73	3-47	4-13	6-06	7-64	8-20	5-50
Patna	4-5	8-49	7-57	6-87	5-78	4-76	3-49	3-61	4-31	5-11	6-94	8-57	8-86	6-22
Jhansi	3-4	1-88	1-47	0-28	28-927	28-795	28-662	28-667	28-753	28-837	0-19	1-74	2-06	28-950
Jubbulpore	3	28-611	28-603	28-525	28-429	3-24	2-05	2-06	2-80	3-09	28-481	28-622	28-646	4-37
Nagpore	3	9-47	8-96	8-08	7-02	6-25	5-28	5-38	6-16	6-42	7-94	9-39	9-83	7-51
Monghyr	3-4	29-860	29-775	29-686	29-587	29-493	29-367	29-376	29-442	29-516	29-686	29-832	29-900	29-627
Hazareebagh	4-5	27-966	27-906	27-851	27-765	27-672	27-558	27-553	27-617	27-677	27-848	27-963	28-005	27-732
Cuttack	4-5	29-985	29-897	29-822	29-708	29-620	29-549	29-547	29-594	29-662	29-821	29-960	30-014	29-765
Saugor Island	5	30-021	9-42	8-79	7-84	6-80	5-57	5-47	5-90	6-66	8-27	9-76	0-41	7-92
Calcutta	5	0-21	9-45	8-69	7-74	6-67	5-52	5-51	6-10	6-79	8-40	9-82	0-42	7-93
Berhampore	4	29-948	8-75	7-90	6-76	5-68	4-42	4-67	5-41	6-24	7-69	9-08	29-975	7-15
Jessore	4-5	9-94	9-21	8-50	7-53	6-66	5-37	5-34	5-99	6-74	8-32	9-67	30-028	7-79
Dacca	4-5	9-79	9-21	8-45	7-77	6-78	5-59	5-58	5-96	6-73	8-17	9-52	0-10	7-81
Cachar	2-3	9-02	8-62	7-98	7-30	6-36	5-45	5-48	5-96	6-80	7-73	9-11	29-939	29-745
Chittagong	5	9-08	8-51	7-88	7-26	6-42	5-37	5-37	5-72	6-34	7-55	8-79	9-33	29-730
Akyab	4-5	9-95	9-29	8-96	8-40	7-53	6-89	6-93	7-11	7-60	8-45	9-51	30-015	8-40
Darjeeling	3-5	23-344	23-322	23-311	23-326	23-278	23-228	23-224	23-261	23-322	23-391	23-424	23-409	23-320
Goalpara	3	29-603	29-522	29-442	29-380	29-286	29-206	29-195	29-247	29-328	29-426	29-567	29-621	29-402
Shillong	3	25-262	25-238	25-211	25-195	25-098	25-060	25-058	25-100	25-172	25-247	25-320	25-324	25-190
Port Blair	2-3	29-719	29-715	29-674	29-630	29-568	29-563	29-574	29-574	29-606	29-639	29-689	29-720	29-639
Madras	4	9-67	9-43	8-98	8-08	7-20	6-71	7-06	7-34	7-54	8-27	9-25	9-78	8-28

TABLE VIII.—MONTHLY MEANS OF ATMOSPHERIC PRESSURES REDUCED TO SEA LEVEL FROM THE  
VALUES IN TABLE VII.

	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
Roorkee ...	30·060	29·972	29·893	29·762	29·613	29·494	29·508	29·567	29·670	29·855	30·027	30·091
Agra ...	·078	·998	·907	·779	·621	·503	·508	·565	·666	·863	·033	·087
Lucknow ...	·084	·989	·900	·766	·632	·516	·525	·593	·689	·868	·036	·098
Benares ...	·094	30·002	·914	·791	·647	·532	·534	·610	·676	·874	·038	·101
Patna ...	·040	29·971	·871	·759	·655	·527	·540	·612	·692	·877	·040	·077
Jhansi ...	·072	30·017	·882	·760	·603	·479	·496	·586	·674	·868	·042	·087
Jubbulpore ...	·018	29·997	·896	·766	·640	·523	·548	·628	·655	·846	·015	·055
Nagpore ...	·004	·941	·837	·715	·632	·537	·563	·643	·670	·830	29·992	·045
Monghyr ...	·030	·944	·850	·748	·653	·526	·536	·603	·678	·849	·999	·070
Hazareebagh ...	·033	·948	·855	·728	·616	·512	·516	·590	·657	·851	·999	·075
Cuttack ...	·069	·980	·905	·790	·700	·630	·628	·675	·704	·904	30·044	·098
Saugor Island ...	·027	·948	·885	·790	·686	·563	·553	·596	·672	·833	29·982	·047
Calcutta ...	·040	·964	·888	·792	·685	·570	·569	·629	·697	·859	30·001	·061
Berhampore ...	·021	·948	·861	·746	·637	·511	·536	·610	·684	·839	29·979	·047
Jessore ...	·015	·943	·871	·774	·686	·557	·554	·619	·684	·853	·988	·047
Dacca ...	·016	·958	·881	·714	·632	·595	·594	·632	·714	·853	·988	·047
Cachar ...	29·979	·939	·874	·815	·710	·619	·623	·670	·754	·848	·987	·036
Chittagong ...	30·003	·946	·881	·774	·733	·629	·629	·664	·726	·848	·973	·038
Akyab ...	·017	·951	·918	·861	·774	·679	·715	·732	·782	·867	·973	·037
Goa ...	·007	·923	·837	·771	·675	·592	·580	·633	·716	·817	·966	·025
Port Blair ...	29·943	·939	·896	·850	·788	·733	·794	·795	·828	·861	·912	29·944
Madras ...	·994	·970	·925	·835	·747	·698	·733	·761	·782	·855	·953	30·005

## DESCRIPTION OF THE PLATES.

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PLATES I to VI show the mean distribution of temperature and pressure in Northern India in each month of the year. The isobars are represented by thick red lines, corresponding to even twentieths of an inch. The value of each is noted against the line, and the signs + and — indicate the directions in which the baric gradient rises and falls. The isotherms are represented by thin red lines, corresponding to equal increments of 5° Fahr.

The charts are based on the data given in Tables III and VIII, with some additions in certain cases (*See note p. 28*). Owing to the absence of barometric data for the Punjab, Assam, and Bombay, the isobars cannot be traced in those provinces.

Plate VII shows the average distribution of the total annual rainfall in Northern India, by means of isohyetic lines, each of which corresponds to an increment or decrement of 10 inches. The chart is drawn up from the data given in Table VI. It does not pretend to show minor local variations, nor to give the details of distribution where the annual rainfall exceeds one hundred inches. The stations enumerated in Table VI. are indicated on the chart by Roman figures corresponding to those of the Table.

The principal characteristics of distribution according to season, are indicated by inscriptions on the chart.

